

**The Structural Playability Process (SPP) -**  
**An Effective Design Process for Educational Computer Games**

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A thesis submitted in partial fulfilment of the requirements for the

Degree

of Doctor of Philosophy

In Human Interface Technology

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2014

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At the Laboratory of Human Interface Technology

University of Canterbury

## Abstract

How to best develop educational computer games is an open question and an active area of research. It is clear that computer games are able to instil the desire for players to rise to challenges, learn new and complex skills, and most of all to be entertained. Researchers are now trying to identify the underlying motivational nature of computer gameplay to harness it for teaching and learning.

This research explores the world of educational game design and development within the field of Serious Games, and presents the Structural Playability Process (SPP) for educational game design and implementation. Serious Games are games designed for a primary purpose other than pure entertainment.

The development of the Structural Playability Process was undertaken through the design and production of two serious games; *GeoThermal World*, which provides a virtual geothermal field-trip experience; and *Ora – Save the Forest!*, a simulation-driven game for pest management in New Zealand forests. Using these games as case studies we describe the four SPP spaces of; education, translation, design, and engine, in support of research into the delivery of effective game design methods that facilitate engagement with educational topics.

The main contributions of this research are in the development of a new, generalisable model of educational game design combined with a practical method for implementing the design into a game engine. The results infer that the SPP approach provides a means for ‘designing-in’ conditions that can support motivation through ‘gameflow’ mapping, and provide support for the impact of serious games on learning; the games designed with the new model increased learning gains post-play and supported knowledge retention. Finally, this research contributes empirical evidence to the field, as the SPP allows for the measurement of learning outcomes which are tracked throughout the design and development process.

**Keywords:** Serious/Educational Games, game-design, Structural Playability (SPP), Flow Theory, motivation, game-play

## Acknowledgements

I would like to express my greatest appreciation to my partner David, for his tireless love, support, understanding and practical help in making this thesis happen; to Dr. Julian Looser for his phenomenal technical skills, contributions and unwavering friendship, and without whom this PhD most certainly would not have happened; and finally to Hilary, my mother, who as a child instructed me to “think about it!”

I would also like to express my sincere gratitude to:

- My supervisory team of Mark Billingham and Tom Furness (HIT Lab NZ), and Niki Davis (College of Education) at the University of Canterbury; for their constructive advice and guidance in my undertaking and completion of this PhD.
- Dr. Jacqueline Dohane, my co-researcher on *Geothermal World*, and Postdoctoral Fellow of Geological Sciences at the University of Canterbury.
- Dr. Penelope Holland, ecological modeller and my co-researcher on Ora – Save the Forest!; and Bruce Warburton, Research Leader at Landcare Research, Lincoln, New Zealand.
- My amazing team of developers; who have worked tirelessly to bring the game projects, at the heart of this research, to fruition.
- The campus health centre team who helped me manage the extraordinary demands of PhD research while coping with the mental health diagnosis of bi-polar disorder.
- My ‘most excellent’ friends who have supported me and kept me going on this journey.

## Declarations

Parts of this thesis have been submitted and/or accepted for publication in advance of this thesis. The publications that I have authored and co-authored are listed below, according to the year of publication:

- Bradshaw, H. (2010). Entertainment Education For The Computer Age: Investigating The Engaging Nature Of Computer Games For Educational Application Skilled Performance And The “ Flow ” State. In ICERI2010 Conference (pp. 3772–3781). Madrid, Spain.
- Dohaney, J., Kennedy, B., Brogt, E., & Bradshaw, H. (2012). The Geothermal World Videogame : An Authentic , Immersive Videogame Used To Teach Observation Skills Needed For Exploration. In New Zealand Geothermal Workshop. Auckland, New Zealand: International Geothermal Association
- Bradshaw, H., Holland, E. P., & Billinghamurst, M. (2014). Ora – Save the Forest! Designing a Social Impact Game. Social Impact Game. In Y. Pisan (Ed.), International Conference on Entertainment Computing (pp. 84–91). LNCS 8770.



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# 1

## Introduction

Computer games have the ability to create intensely motivated individuals who are able to perform intricate tasks, learn new skills and apply complex reasoning. However, how to best develop educational computer games is an open question and an active area of research. This research explores the world of educational computer game development to deliver an effective game design method that facilitates engagement with educational topics.

Computer games have grown from simple roots with the release of Pong (1972); a tennis style game, to the global phenomena it has become today, supporting huge online worlds hosting millions of networked players. The sophisticated and ubiquitous nature of computer games can be likened to the rise of film and television and constitutes an important cultural phenomenon.

In 2012 consumers spent \$20.77 billion USD on video games, hardware and accessories. This expenditure is predicted to rise to \$24 billion USD in 2014. Of this 40% of game sales included digital content, subscriptions, apps and mobile games (Galarneau, 2014). The rise in computer games is fuelled by their inherent ability to induce enjoyment, with players experiencing a range of positive emotions such as optimism, curiosity and determination (McGonigal, 2014).

It is clear that computer games are able to instil the intrinsic desire for players to rise to a challenge, to learn new and complex skills, and most of all to be entertained. Researchers are now trying to identify the underlying motivational nature of gameplay and harness it for teaching and learning (Aguilera & Méndiz, 2003; Boyle, Connolly, & Hailey, 2011; Dondlinger, 2007; Wouters, et al., 2013).

An example of harnessing gameplay for good can be seen in the success of Foldit (Cooper et al., 2010; Khatib et al., 2011). Foldit is a crowd-sourcing multi-player online game for predicting protein structures that doesn't require a scientific background to participate. The goal of the game is in the production of accurate protein structure models through gameplay mechanics. Foldit's success came in 2011 when players from around the world provided a solution to a protein structure folding problem that had

escaped scientists for the past decade. When presented with this problem through gameplay the players found the correct solution in only ten days.

As can be seen by this example games can excel at motivating people to get involved in complex problems, and is an area where other mediums for dissemination do not reach. However, to make the most of the power of educational gameplay, research has to be conducted into how to effectively construct these environments. Understanding human motivation and designing skill based, goal related tasks to match the capacity of the human mind is becoming an important challenge if we wish to engage a society of tech savvy game players.

In order to address this area of research, the work in this thesis focuses on the design and production issues of education based Serious Games. The applications for gaming subjects within Serious Games are numerous with topics covering defence, scientific exploration, health care, emergency management, city planning, engineering, religion, politics<sup>1</sup> and so on.

Serious Games have been defined by researchers as ‘games which are intentionally designed for the purpose of learning, skill acquisition and training’ (Jennett et al., 2008), with the purpose of a Serious Game being twofold: (i) To be fun and entertaining, and (ii) To be educational (Bellotti, et al., 2013). In general, serious games can be described as a game designed for a primary purpose other than pure entertainment. However, the process of producing a Serious Game can be further studied.

Producing a computer game project is a complex process; each element of the game brings with it a set of needs and requirements. Foremost, the game must deliver a fun and rewarding experience. It must also have an interface that enables the player to interact seamlessly with the gameplay and designed content. It is often necessary to develop a game within a limited budget and timescale.

It should have an art style, graphics and user interface that portrays a story and supports player immersion and enjoyment. It should have an engaging premise and plot. It should provide a gameplay goal and progression. It should have challenges and rewards, and most importantly in terms of educational gameplay, it should meet its intended learning outcomes. It should also provide stable and engaging interactions that can be programmed within a game engine. These interactive components of the gameplay can be described as game mechanics.

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<sup>1</sup> [http://en.wikipedia.org/wiki/Serious\\_game](http://en.wikipedia.org/wiki/Serious_game)

For example, Hunicke, Leblanc, & Zubek, (2004) states 'mechanics are the various actions, behaviors and control mechanisms afforded to the player within a game context. Together with the games content (levels, assets and so on)'. While Schell, (2008) p41 describes mechanics as 'the procedures and rules of your game. Mechanics describe the goal of your game, how players can and cannot try to achieve it, and what happens when they try.' Salen & Zimmerman, (2004) p316, put it even more simply that 'core mechanics create the patterns of behaviour, which manifest as experience for players.' They go onto elaborate that a core mechanic can be a single action such as a footrace with the mechanic being running. Alternatively they also state that core mechanics can be 'a compound activity composed of a suite of actions'. Such as firing a weapon which can include the actions of aiming, firing, managing health and ammo. Although the definition of a game mechanic is broad, simply put they are the mechanisms that provide and support player interaction with the gameplay.

In Fig 1.1 the typical development process of a game project is visualised as a set of intersecting circles (left). These represent the overlapping nature of the different parameters of the design and development process. Each game project has its own set of unique 'circles' with different emphasises based on the games intended genre, style of play and gameplay content. No two game projects are identical, and at the start, each is a unique and unknown entity. This complexity inherent in developing a game brings a challenge for educationalists in ensuring that their intended educational content does not get submerged or obfuscated in the realities of game production.

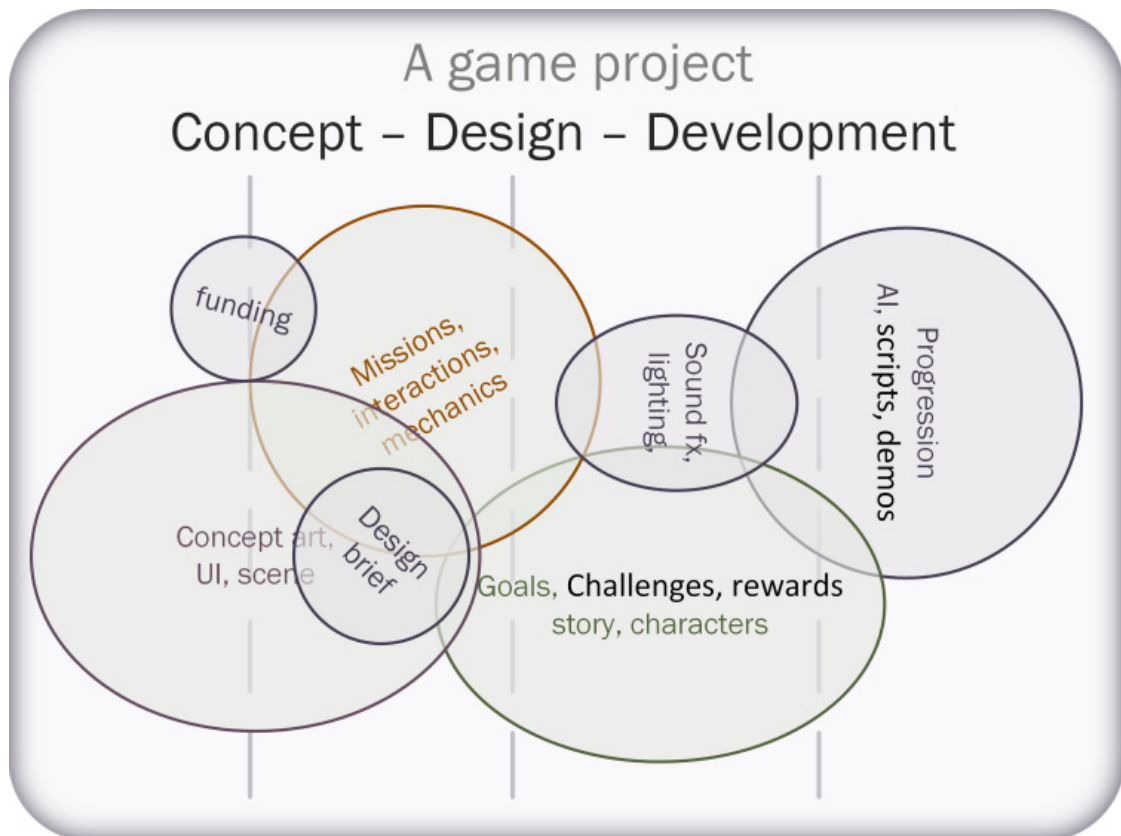


Figure 1.1 – diagram representing the complexity of a game project

Due to these realities of game project production there is a tendency for research in this field to focus on the theory supporting educational game design, while falling short of directly addressing the complexities of practical implementation. We argue that what is required in the growing field of serious games is for research that addresses the separation between academics who are working towards higher level design theories, and the instructional/game designers who implement the gameplay mechanics of enjoyment.

The main contributions of this research are in the field of Serious Game production, through the development of a new, generalisable model of educational game design; the Structural Playability Process (SPP). This model not only builds upon valid learning theories, but addresses the complexities of practical implementation through the development and testing of two very different game projects and the creation of an in-engine designer's interface for structuring and tweaking player experience.

Other important contributions of this PhD include:

- The development of two serious games;
  - *GeoThermal World*; providing virtual geothermal field-trip experience and is currently being used by Geology students to augment their learning.

- *Ora – Save the Forest!*; a simulation-driven game for pest management in New Zealand forests. Scheduled for public release in late 2014.
- Advancing educational game design methods:  
Introducing Skilled Performance (Fitts & Posner, 1967) theory as a scaffolding method as a means for ‘designing-in’ motivation conditions that support a players’ ability to stay on task and reach gameplay goals.
- Providing support for the impact of serious games on knowledge acquisition:  
The experimental studies determined that the two games designed with the new model increased learning gains post play and supported knowledge retention.
- Contributing empirical evidence to the field:  
The design process allows for the measurement of clearly set learning outcomes, which are tracked throughout the design and development process.

This PhD research is a multidisciplinary work primarily situated within the field of Interaction Design. It draws upon educational practice, learning and motivation theories, and game design principles. It offers an exploration and investigation into the design and development properties of educational games. It presents a design process that provides a practical translation of educational design theories into game production methods.

The theories in this thesis have been tested in the development of two real-world game projects in collaboration with the department of Geological sciences at the University of Canterbury; with ‘*GeoThermal World*’, and ecological scientists from Landcare Research; and with ‘*Ora – Save the Forest!*’, as part of their community participation research programme, aimed at increasing in pest management decision-making.

The author has worked within the field of game design and education for a number of years, undertaking a Master of Arts in Design (Strategy and Innovation) with a specialisation in computer game playability design. During this time the author contributed to the field of educational game design through the development of a theoretical game design model termed the Structural playability model (SPD), which will be covered in more detail in Chapter 2. The MA work was followed by teaching in



higher education as a senior lecturer within the field of creative technology, again with a specialism in computer game design and development.

## **1.1 Research Question**

The goal for this PhD research was to further explore the concept of Structural Playability, by building upon the theoretical SPD model, with the intent of reworking the concept of Structural Playability into a practical method that could be applied in real game development projects. This intention was informed by the findings from the review of related works, game design models, frameworks, and approaches. As a result a question was formed through which the research for this thesis was focused:

***What is an effective design process for computer games that deliver structured learning activities?***

This question asks not for the optimal answer as in ‘what is the MOST effective...’ but it asks for the satisficing answer as in ‘What is AN effective...’. Satisficing is a term coined by Simon, (1956) in which he states that ‘Evidently, organisms adapt well enough to ‘satisfice’; they do not, in general, ‘optimize’. ‘A ‘satisficing’ path is a path that will permit satisfaction at some specified level of all its needs’. So what is wanted in this situation is not the most effective solution but what is a possible effective solution.

Let us now define the intention of the question, from which we can gain clarity of meaning for the proposed research.

### **What is meant by:**

- **Effective;** that students learn what is intended for them to learn through interaction with the game and that they experienced a sense of engagement with the topic. Being effective does not mean the design process is efficient, only that it is effective and suited to its intention. Players/learners should not just learn how to play the game rules or to win in the game scenario. It also should enable students to perform tasks outside of the game that are related to the learning that has taken place within the game; this is termed Transfer.
- **Design process;** the process that games designers apply when developing computer games. In this case the design process covers the design of the game concept and the implementation of the game mechanics directly governed by the design. This does not include the production of assets or code. The process will attempt to align learning outcomes with gameplay objectives for practical implementation, but would not be optimised for development efforts such as

budgetary efficiency. Defining the parameters of the 'design process' leads to the further challenge of defining what level of detail is most appropriate for the prescribed design process. The definition of design process in this context is focused on the design of the game, and is not extended into how the user then chooses to apply the game, such as in a classroom setting or Lab.

- **Computer games;** is an umbrella term that encompasses video games, PC games, console games, handheld games and digital games. Computer games in this sense, is also a term that encompasses all games that teach something, whether intended for education or entertainment. However, for clarity, the computer games in this thesis are Serious Games that are intended to be used for educational purposes.

A game primarily generates a scenario where enjoyment can be achieved, and this is done through a combination of methods intended to be playful. If it is not playful in nature then it is not a game. Most likely, it is a simulation, although enjoyable simulations can be games. O'Neil et al., (2005) takes care to establish the difference between what constitutes a game and a simulation, when reviewing learning outcomes in the context of computer games.

He provides a 'summary of the characteristics that various researchers have attributed to games and to simulations'. Characteristics particularly relevant to this thesis are; that games have rules that are defined by a game designer/developer rather than a simulated system, and that the goal of a game is to reach a win state rather than to discover cause-effect relationships. Most importantly, when considering the design of a motivating and optimal experience, a game is intended to be playful and a simulation is not.

- **Structured learning activities;** are characterised by having defined learning outcome/s that form the basis on which the gameplay is built. For the purpose of educational games, this comprises a series of skill based tasks generating a progression path towards the end goal/s. Goal driven progression is balanced against a system of rewards and feedback from which the learner can judge and modify their actions and interactions within the gameplay structure. Fitts & Posner, (1967) state that 'we learn through acquiring skills and skilled performance always involves organised sequences of activities. Organisation, goal directedness and utilisation of feedback are basic characteristics of a skilled performance'. A structured learning activity will preferably lead to knowledge that is transferable outside of the game world.

In the context of this research the terms transfer and transferable is termed as; knowledge learnt in the game world applied to a knowledge test outside of the game world. The degree of transfer being assessed as a knowledge acquisition score.

The next chapter provides an overview of the related work through a review of literature, and an introduction to the authors' previous research in the field. The background context of the author's previous work frames the research contribution of this thesis, by exploring the concept of 'structural playability design' through the lens of Fitts and Posner's (1967) Skilled Performance theory and the author's SPD model of gameplay design.

Chapter 3 presents the research approach and Chapters 4 to 7 describe the game projects. Chapter 8 provides an evaluation of the research outcomes and Chapter 9 closes with concluding remarks and directions for future work. Figure 1.2 provides an overview of the thesis chapter structure to aid navigation. The dotted line linking Chapters 3 and 8 indicates that the reader may jump forward to chapter 8 to gain a compressed overview of the research before returning to the details of the two game projects.

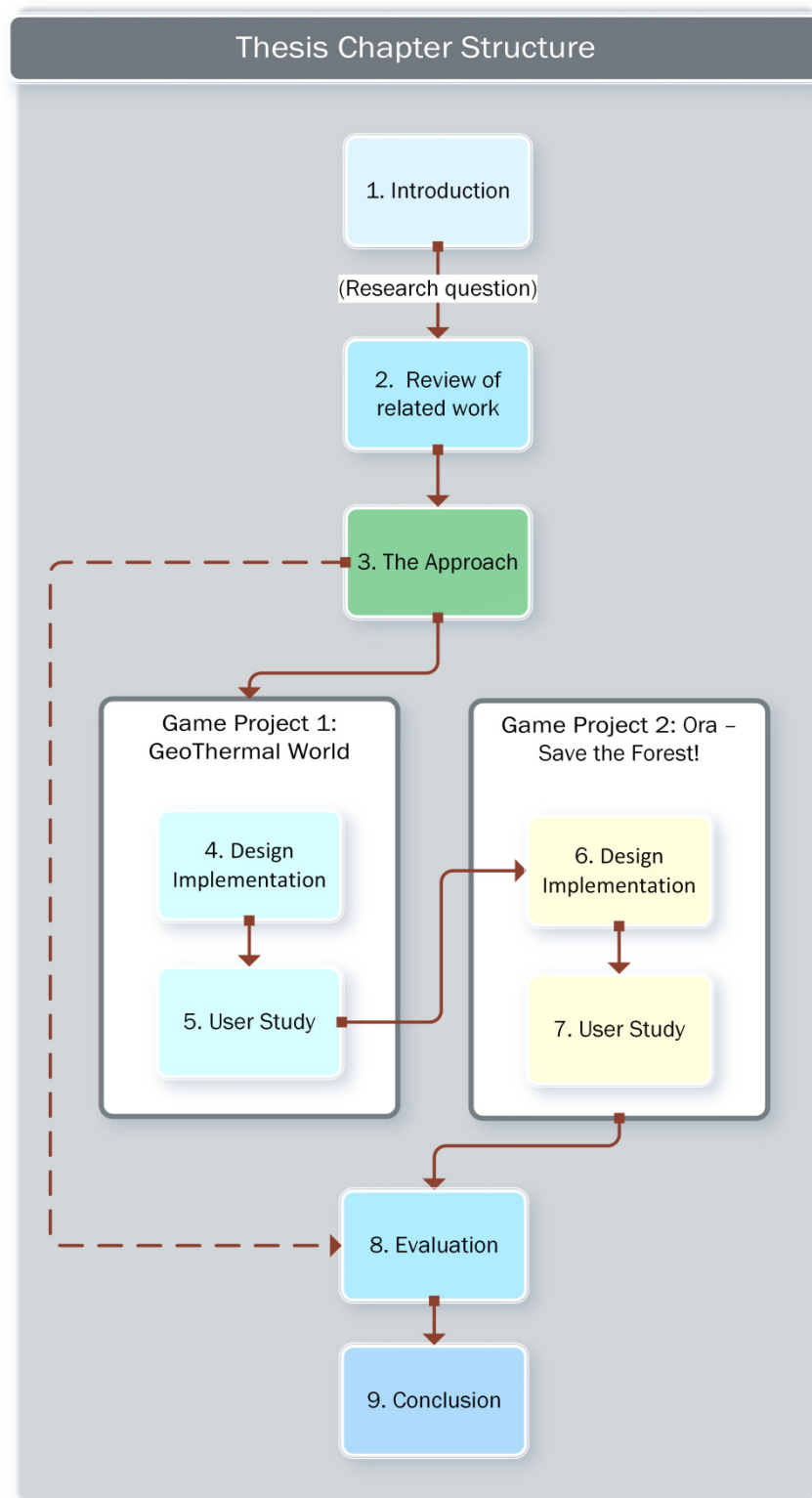


Figure 1.2 – Thesis Chapter Structure

# 2

## Review of Related Work

The field of serious game design research is a complex and open area for research. In the introduction we argued for research that addresses the gap between theory and practise. This chapter provides an overview of the main themes that contextualise the scope of the research on this topic. The main themes being; motivation and skill learning, learning outcomes and empirical evidence, approaches to design and development, and assessment instruments. A discussion of these research themes will follow before the final section which will introduce the authors' previous educational game design research work. The contributions of the authors' previous work in the context of the PhD research will be presented in the final section of this chapter.

The literature reveals motivation as a key to engaging gameplay, and that there is a need for structured learning outcomes that better support the collection of empirical evidence. A review of design models also reveals the need for improved models that provide practical steps for the design and implementation of learning gameplay.

The main research focus for this thesis is education game design, and the problem being addressed is how to best design serious games so they can be used in an educational context.

### **2.1 *Serious Games***

The literature reviewed here comprises of articles published between 2003 and 2014, which reviewed material ranging from the 1970s and 1980s, when video games first began to play a significant role in society, until present day. The reviews consider entertainment and educational games which present research on their educational application. The latter reviews address the development of educational game design through a range of approaches and models, discussed in more detail in the following section.

The research literature reveals several perspectives on the value of educational games, supporting the abilities of educational games to motivate and support skill learning, to provide knowledge acquisition

and content understanding, and research addressing design, development and the assessment of educational games. There is also a growing consensus that, as educational games have become more prolific in recent years, there is a need for further empirical evidence to support their effectiveness. In particular, a move towards experimental design outcomes, such as ‘randomized control trial’ studies. On the whole the varying perspectives, albeit to different degrees, collectively agree that educational computer games do have the potential to operate as effective learning environments and in the future they will become part of the norm. This will now be presented through the following sections; Motivation and Skill learning, Learning Outcomes and Empirical Evidence and in Approaches to Design and Development.

### **2.1.1 Motivation and Skill Learning**

Aguilera and Méndiz, (2003) review game studies from an educational perspective, covering 30 years of literature (1970-2000) with the intention to investigate the use of games as teaching and learning tools. They find that ‘in addition to stimulating motivation, video games are considered very useful in acquiring practical skills, as well as increasing perception and stimulation and developing skills in problem-solving, strategy assessment... and obtaining intelligent answers’. Dondlinger, (2007) in her later review, agrees with the findings of Aguilera and Méndiz, stating that that ‘video games do affect learning, and games motivate players to spend time on task, mastering the skills a game imparts’. Like Dondlinger, Aguilera and Méndiz find research that supports the positive effect of video games on skill and cognitive development.

Dondlinger’s review goes further than that of Aguilera and Méndiz with a focus on ‘how video games can be designed to facilitate learning’, rather than just how they can be used. Her review consists of ‘publications analysing educational game design’ and those that present ‘elements conducive to learning, theoretical underpinning of game design and learning outcomes’. She presents elements of effective video game design which encompass motivation, narrative context, goals and rules, interactivity and multisensory cues.

Dondlinger’s focus on how games can be designed to facilitate learning informs the research in this thesis by providing five clear findings that address some the main aspects in serious gaming. Table 2.1 summarises Dondlinger’s five key findings (left) alongside a list of studies (right) that support those points. Dondlinger findings are useful in the context of this PhD research as items 1 to 4 provide some key contextual points that highlight the core of research in this field, while point 5 articulates the research problem at the core of this thesis. The findings from the supporting literature studies are addressed within the body of this chapter.

Table 2.1 – The five key findings of publications analysing educational game design

Key Finding	Supporting Literature
1. Video games do affect learning.	Bellotti, et al., 2013; Connolly, et al., 2012; Wouters et al., 2013
2. Games motivate players to spend time on task, mastering the skills a game imparts.	Boyle, Connolly, & Hainey, 2011; Jennett et al., 2008; Kühn, et al., 2014; Ryan & Deci, 2000
3. There are disagreements among researchers over the specific characteristics that provoke motivation.	Przybylski, et al. 2010; Molins-Ruano et al., 2014; Wouters et al., 2013 Mcclarty, Frey, & Dolan, (2012)
4. Some distinct design elements such as narrative context, rules, goals, rewards, multisensory cues and interactivity seem necessary to simulate desired learning outcomes.	Cowley et al., 2008; Finneran & Zhang, 2003; Linehan, et al., 2011; Wei & Li, 2010; Wiebe, et al. , 2014 Sweetser et al., 2012
5. A better understanding of educational game design will lead to production of improved educational games.	Arnab et al., 2014; Dunwell et al., 2012; Linehan et al., 2011; Turkay, et al., 2014)

Boyle, Connolly, et al. (2011) address the role of psychology in understanding the impacts of computer games. They address motivation in terms of self-determination theory (Deci & Ryan, 1985; Ryan & Deci, 2000), Flow (Csikszentmihalyi, 1990), and immersion (Jennett et al., 2008). Immersion is an experience in one moment in time involving a lack of time-awareness, a loss of awareness of the real world, involvement and a sense of being in the task environment. They consider the worth of both Commercial Off-the-Shelf (COTS) games and serious games. They consider games to provide engagement, stimulation and challenge with the potential to support 'learning, skill acquisition and attitude and behaviour change'. They conclude that developing games for learning or behaviour change is complex and that the 'design of games, knowledge of the relevant content or subject area, knowledge of motivation, pedagogy and behaviour change' is required to produce successful games.

Przybylski, et al., (2010) also address games from a psychological standpoint, providing a deeper investigation of motivation through a theory based 'model for video game engagement.... based on self-determination theory'. They review empirical evidence from a range of studies that include 'the determinates and effects of immersion'. From their study they determine 'that video game engagement can be effectively studied and understood through the proposed motivational lens' with emphasis on the effects of immersion on goals and decision making. Although this study provides support for the motivational power of gameplay through self-determination, they do not address the wider aim of serious games in the support of knowledge acquisition. However, a recent study that undertook to design games to improve student motivation found that 'the use of serious games in the learning process increases motivation when it is compared to the motivation induced by traditional learning techniques'(Molins-Ruano et al., 2014).

Bellotti, et al. (2013) review serious game studies and provide an overview of assessment 'in and of serious games'. They conclude that 'results suggest that game-based learning is effective for motivating and for achieving learning goals' but at the lower end of Bloom's taxonomy levels<sup>2</sup>. They also consider Flow to be another key characteristic of a game experience and advocate for assessment of Flow in games through GameFlow evaluation (Salen & Zimmerman, 2004) (Fu, Su, & Yu, 2009; Sweetser & Wyeth, 2005). They argue for improved assessment design where clear goals must be set, followed by techniques to collect data that will be used to verify these goals. Bellotti finds that learning outcomes in serious games are under studied.

In this section Dondlinger's (2007) findings suggest key areas, within the Serious Game literature, that practitioners should be aware of, while confirming that the field of Educational Game Design requires development if educational game production is to be improved. Both Boyle, Connolly, et al. (2011) and Przybylski, et al., (2010) indicate that the field of psychology, especial in terms of motivation, has useful contributions to make to this field. Bellotti, et al. (2013) in particular indicates that, apart from an understanding of motivation, the role of learning outcomes in gameplay also require deeper investigation.

### **2.1.2 Empirical Evidence and Learning Outcomes**

In the previous section we touched upon the need for further investigation into the role of learning outcomes in gameplay to support the impact of game-based education. Here we discuss a range of reviews and studies that provide further insight into this area. We begin with O'Neil, et al., (2005) who

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<sup>2</sup> ( see Krathwohl, 2002)



take a very structured approach to their review, considering only studies that include empirical evidence over a range of fifteen years. They find that ‘games have the potential to induce learning due to their qualities of fun and motivation but find no direct evidence to confirm they promote learning’. They find that ‘the evidence of potential is striking, but the empirical evidence for effectiveness of games as learning environments is scant’. They conclude that for the potential of educational games to be reached, methods for clearly structured learning need to be developed.

However, later reviews undertaken separately by Bellotti, et al. (2013) and Connolly, et al., (2012) find that ‘that the most frequently occurring outcomes and impacts to be ‘knowledge acquisition/content understanding and affective and motivational outcomes’. This indicates that the evidence supporting the potential of games as learning environment has grown since 2005.

Connolly, Boyle, et al., (2012) apply the same structured approach as O’Neil reviewing papers that provide ‘empirical evidence relating to the impacts and outcomes of playing games’. They consider 129 papers that meet their inclusion criteria, falling between 2004 and 2009. They state that the high number of papers returned by their search criteria indicate a surge in interest in games for learning and Serious Games. Their review builds upon the findings of O’Neil, in establishing further empirical evidence that supports the ‘effectiveness of games-based learning’. Similarly to O’Neil they consider that ‘more randomized control trials to provide more rigorous evidence of their effectiveness’ are required of these types of game.

McClarty, et al., (2012) also highlights the mixed nature of empirical support, in line with Connolly, Boyle, et al. and O’Neil, et al. Their review considers a range of studies including games not specifically designed for educational purposes. They consider theoretical and empirical evidence to support of the value of digital games. However, while they find theoretical support for the benefits of digital games in learning and education, there is mixed empirical support’. Although McClarty doesn’t detail the nature for the mixed empirical support, their study advocate for creation of ‘definitions and models that are considered integral parts of the power of games (e.g., motivation, engagement, agency)’.

Interestingly, Wouters, et al. (2013), who undertook a meta-analysis of the cognitive and motivational effects of Serious Games, proposes that ‘Serious Games influence learning in two ways by changing cognitive processes and by affecting motivation’. They conducted an analysis of 35 studies focusing on learning and retention, and motivation; finding that Serious Games were more effective in terms of learning and retention but they were not more motivating than conventional instruction methods.

These findings are somewhat in contrast to the consensus view of Bellotti et al., (2013); Boyle et al., (2011); McClarty et al., (2012) that motivation appears as a strength of gameplay. However, their findings do provide an illustration of the need for further empirical evidence, to fully understand the impact that educational gameplay has on learning or motivation.

In the search for empirical evidence, research by Girard, et al., (2013) attempted to identify all the experimental studies that used serious games for training or learning and assessed their results in terms of both effectiveness and acceptability. Although they don't specify a time frame for the range of their search they found only 9 studies that met their criteria. The main limitations they found with these studies lies 'not only of the empirical studies selected for the review', but also in the inconsistent use of the concept of 'control group', in the majority of the Serious Games and video games studies they reviewed. Of the 9 studies they found, a classical pre-test/post-test design was used with three types of measures; (1) knowledge questionnaires, (2) academic tests and (3) cognitive tests. Again, like O'Neil and Connolly, they find a 'clear lack of empirical studies investigating the effectiveness of serious games in learning'.

Although the findings from Girard, et al., (2013) are clear, they offer no suggestions as to why this is the case or how it can be remedied. However, it does point to a need for more structured learning within learning gameplay design that would support these types of experimental studies. This indicates that definition of clear learning outcomes in educational games would go some way to support an increase in sound empirical data.

However, returning back to the topic of motivation, Girard, et al., (2013) also found that some of the experimental studies (Annetta, et al., 2009; Kebritchi, et al., 2010; Wrzesien & Alcañiz Raya, 2010) used post-test questionnaires to investigate the level of engagement on motivation or satisfaction, optimal experience or Flow (Csikszentmihalyi, 1990), highlighting the continued importance of motivation as an aspect of serious games.

In light of Girard's small sample size it is challenging to apply a generalisable outcome from their results, but they do 'stress the beneficial aspects of the development of serious games, which could prove to be the educational tools of the future'.

From the research reviewed in this section, it appears that games can impact player knowledge acquisition and motivation. However, due to a lack of empirical studies, especially those using an

experimental design, it is challenging to establish with any degree of certainty, as to what level and in what manner this is the case. This leads back to the need for structured learning within games perhaps with more emphases in the inclusion of clearly defined learning outcomes, as suggested by O’Neil et al., (2005), and illustrated by the fact that Bellotti et al., (2013) found learning outcomes to be under studied.

### **2.1.3 Approaches to Design and Development**

In the previous two sections we presented a range of views from current literature that touch upon the motivational and cognitive impacts of computer games. We also highlighted a lack of empirical evidence that could prove the worth of these impacts. This thesis is concerned with the development of game design methods that can be effective in supporting a structured, motivational and engaging experience with educational topics. Therefore, this section will attempt to frame and contextualise the current situation for the design and development of serious games.

To recap, Aguilera & Méndiz, (2003); Connolly et al., (2012); O’Neil et al., (2005) present analysis on the value of games in education but do not define strategies for their design. Whereas Dondlinger, (2007) and Bellotti et al., (2013) list a number of distinct design elements; narrative context, rules, goals, rewards, multisensory cues and interactivity. While calling for research investigations that provide a better understanding of educational game design. This supports the views of Connolly et al., (2012); Girard et al., (2013) and O’Neil et al., (2005) who consider that, for the potential of educational games to be reached, methods for clearly structured learning need to be developed. Turkay et al., (2014) agrees in that, the process of merging the disparate goals of education and game design appears problematic, and there are currently no practical guidelines for how to do so in a coherent manner.

To illustrate the impacts that games can have, Kühn, et al., (2014) observed in a study of brain plasticity using Nintendo’s Super Mario, that ‘video game training augments grey matter in brain areas crucial for spatial navigation, strategic planning, working memory and motor performance’. Although the positive physiological effects of gameplay are becoming more apparent, Linehan et al., (2011) finds ‘few practical recommendations made on how to recreate the motivation seen in entertainment games when designing educational games’. This makes a case for better educational game design methods, to recreate what has been found in entertainment based games.

This leads into the view of Turkay et al., (2014) that, ‘educators outside the field of games research and game culture in general’, may find application of Serious Games in a teaching setting ‘somewhat inaccessible’. We propose that this is perhaps exacerbated by a mismatch between the design

methodologies currently used to develop games, and those teaching and learning methodologies understood by educationalists.

Another criticism levelled at educational games is a tendency to focus on delivering learning over fun and engagement, with Linehan et al., (2011) agreeing that ‘perhaps the majority of educational games can be described as chocolate-covered broccoli (Bruckman, 1999) neither fun, nor of educational benefit’. So although the focus should be on the inclusion of well structured learning, it must not be at the expense of the motivational and fun qualities that entertainment based games have in abundance.

The remainder of this chapter will now provide an overview of educational game design models, and assessment instruments, which contextualise the approach to the design and development of serious games.

#### **2.1.3.1 Design Models**

A review by Wei & Li, (2010) focuses on research which explores the design and development of educational games and provides a summary of the ‘educational design models’ that researchers have developed. Wei concludes that the ‘design of educational games is the key to the balance between education and games’. Although Wei draws no conclusions as to the effectiveness of games for education, the review does offer a critical overview of the emergent research which is attempting to align educational theory with gameplay enjoyment. Wei states that ‘the design of educational games is an attractive field that deserves long-time research and thorough exploration’.

Wei & Li, (2010) undertake their review from the perspective of Egenfeldt-Nielsen, (2007) who provide a three generational model of educational game design; a historical construct of learning theory by which researchers can ‘outline the development features and directions of educational games in different historical periods’. Wei, like Dondlinger, puts forward several theories for designing educational games, including Situated Cognition, Flow theory and Experiential Learning theory. Also like Dondlinger, he then considers the approaches to educational game design where motivation appears to be a key aspect to successful learning outcomes.

Motivation and Flow theory are recurring aspects of gameplay for both entertainment and educational games. Flow features in many of the design and development models created to explore the nature of educational game design.

Flow theory (Csikszentmihalyi, 1990, 1997) describes a channel of motivation that balances challenge and skill (Fig. 2.1) resulting in the feeling of enjoyment. It is an eight stage theory which tries to understand how people absorbed in a task reach a state of optimal experience, where motivation is

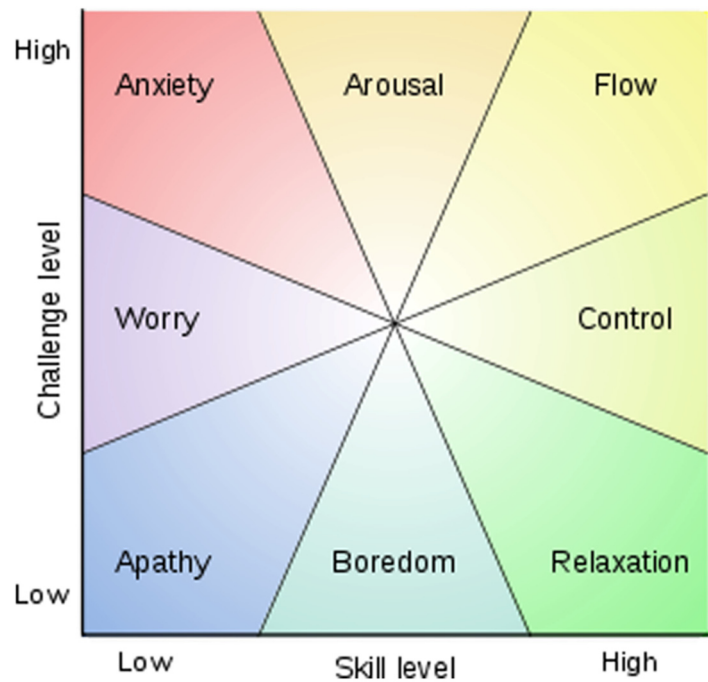


Figure 2.1 - Mental state in terms of challenge level and skill level, according to Csikszentmihalyi's flow model (1997)

intrinsic and autotelic; having an end or purpose in itself. The eight stages comprise of; 1) a challenging activity that requires skills, 2) the merging of action and awareness, 3) clear goals, 4) feedback, 5) concentration on the task at hand, 6) the paradox of control, 7) the loss of self-consciousness, and 8) the transformation of time. Section 3.1.2 of this thesis provides further detail on Flow and its relation to gameplay design.

Gameflow is a term that has emerged from the work of Csikszentmihalyi to describe the pattern of enjoyment and pleasure experienced during gameplay. Salen & Zimmerman, (2003 chp.24) use gameflow to describe the 'play of pleasure'. They discuss it in terms of being able to sculpt desire with the focus on goals and rewards in achieving the 'Flow redux' between boredom and anxiety.

Wei presents several models which utilise Flow theory; Kiili, (2007) Experiential Gaming Model (EGM), Garris' (2002) IPOGM (Input-Process-Outcome Game Model) and Amory, (2006) GOMII (Game Object Model). Additional models which build upon the concept of Flow in educational game development include Finneran & Zhang, (2003) Person-Artifact-Task Model (PAT) and Cowley et al.'s (2006) User-System-Experience model (USE).

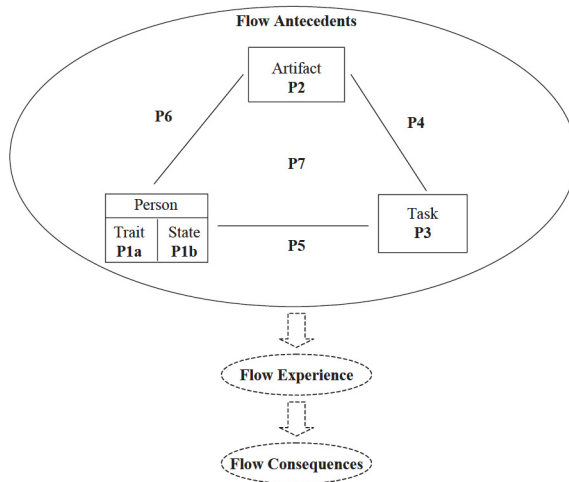


Figure 2.2 - Stages of Flow and The Person-Artifact-Task (PAT) Model of Flow Antecedents; Finneran & Zhang (2003)

### Person-Artifact-Task Model

The Person-Artifact-Task (PAT) model (Finneran & Zhang, 2003) Fig.2.2, is used as a method for taking into account the significance of Flow theory in an IS/HCI context. They suggest that in a computer mediated environment there is a third component to how Flow is normally experienced by a person. Flow normally takes place between the person and the task, but in a computer-mediated environment an artefact such as a computer programme generates a new set of parameters that influences optimal experience (Flow). They state that by

‘separating the task from the artefact, researchers can study factors that influence flow from different aspects’. The PAT model is put forward as a means to ‘clarify ambiguous flow constructs such as the balance between skills and challenges’.

This work has been adopted and adapted by (Kiili, 2005) and Cowley et al., (2006) in development of their respective Flow based models. What Kiili and Cowley attempt is the creation of models that deal specifically with the analysis, design and development of educational computer games as opposed to the broad based application of computer-mediated environments.

### Experiential Gaming Model

Kiili's (2005) Experiential Gaming Model (EGM) utilises the PAT method of dealing with Flow, which he first presents in a framework of Flow in computer-mediated environments (see Fig. 2.3). The EGM model build upon the PAT method through the inclusion of the ‘artifact’, combined with Kolb's, (1984) experiential learning model, which ‘stresses the continuous nature of learning and the appropriate feedback which provided the basis for a continuous process of goal-directed action’. Feedback and goal-directed action are key components of Flow and also represent key functions of how gameplay creates player enjoyment. Kiili states that the main purpose of his model is to ‘link gameplay with experiential learning in order to facilitate flow experience’.

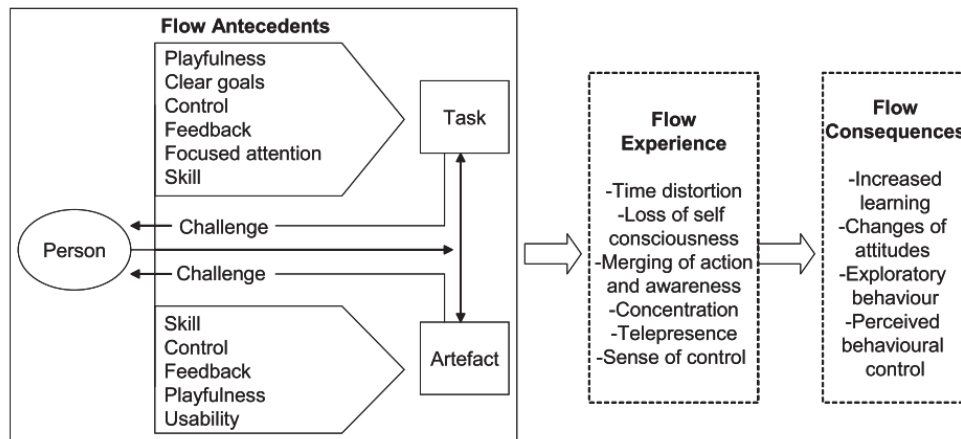


Figure 2.3 - Killi (2005) Adapted PAT model. A framework of Flow in computer-mediated environments

Killi's EGM model (see Fig. 2.4) 'pumps challenges' to the player that induce the Flow condition of intrinsic-motivation. The player then overcomes the challenges via an ideation loop split into 'Preinventive idea generation' and 'Idea generation'. These are then fed back into the new set of challenges and problems defined by the gameplay. Killi states that this model can be used in the design and analysis of educational games, but presents no defined method for actually doing this. Its main strengths are its ability to 'link educational theory and games designing'. However, it appears that this is a theoretical model that has minimal direct application to game mechanics and gameplay design in educational games.

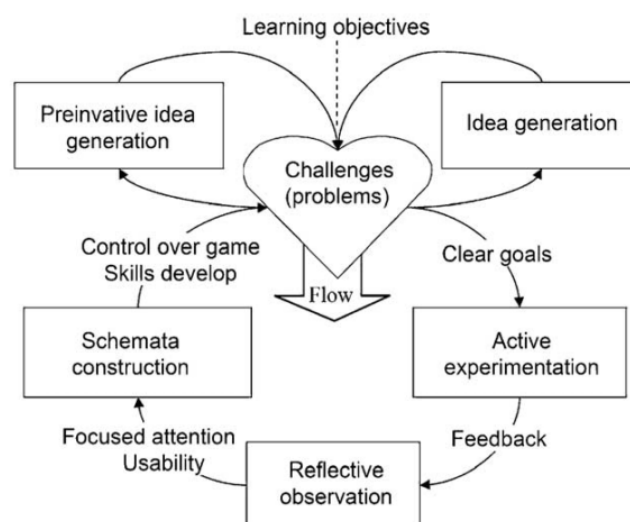


Figure 2.4 - Killi (2005) Experiential gaming model

### User-System-Experience model

Cowley et al., (2006) in his User-System-Experience model (USE) (see Fig. 2.5) also utilises PAT for its 'logical propositions describing how Flow experience is produced'. Although they contend that the PAT system primarily describes production-oriented systems where Flow is an extrinsic part of the model.

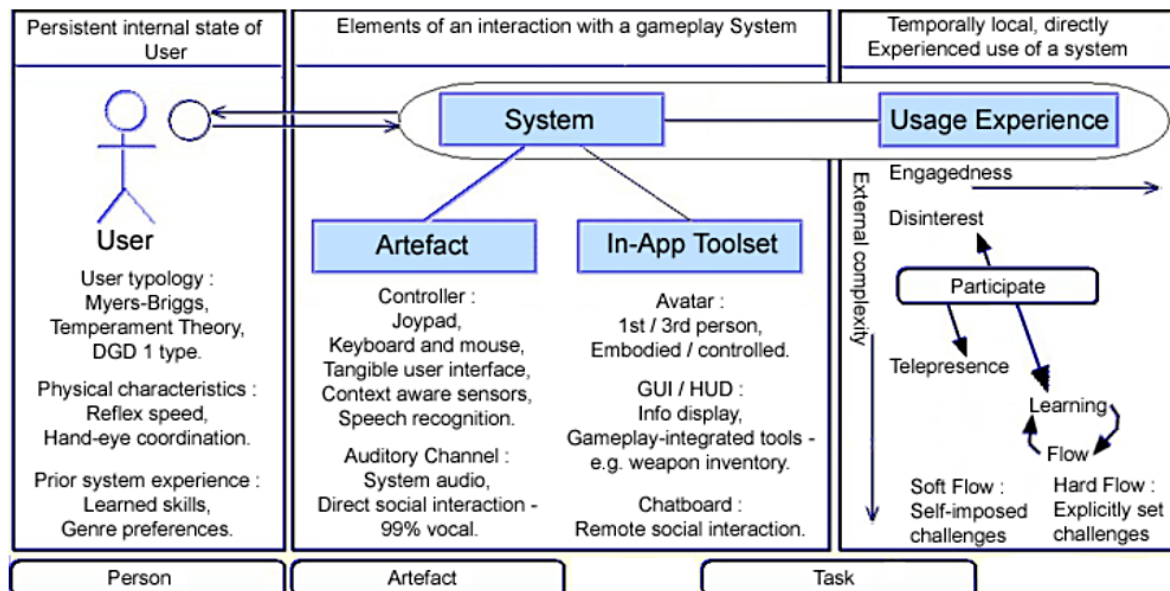


Figure 2.5 - Cowley 2006, *The USE model for virtual interactive entertainment, e.g. computer gaming*

In gameplay, Cowley et al. contend that it is experience over production that is important, such as the differences between usability and playability. Therefore they propose that the USE model integrates Flow as intrinsic to the interaction space. They do this because 'flow has a dependency relationship with learning, which has a profound effect on gameplay'. Crowley states that in any given gaming experience flow depends on the players' engagement and learning potential, and learning occurs through clear goals and immediate feedback. So, if there is a lack of learning then there can be no Flow experience.

Their model consists of three parts directly reflecting the PAT model. It defines User Experience (Task) as the generator of Flow that in turn is linked to the System (Artifact) which is then linked to the User (Person). Where this model is more closely related to gameplay and game mechanics, is in the System (Artifact) interaction. A distinction is made between the In-App Toolset, such as Avatar and Graphical User Interface (GUI) and the Artifact, such as joypad, keyboard or mouse. The USE model, unlike Kiili's EGM model, attempts to understand Flow as a consequence of learning in direct relation to the features of gameplay, such as interaction with an avatar.

Although this model is closer to the design properties of a game than Kiili's, it still does not address the process a designer should take in building an educational game, so remains highly theoretical.



### *Input-Process-Outcome Game model*

An early model worthy of mention is Garriss' (2002) Input-Process-Outcome Game model (IPOG) (see Fig. 2.6) with the features of the Game Cycle represented in three stages defined under Process. The Input stage supplies the instructional content and the game characteristics, while the Game Cycle is an iterative process of user judgements, behaviour and system feedback. This results in a debriefing of learning outcomes.

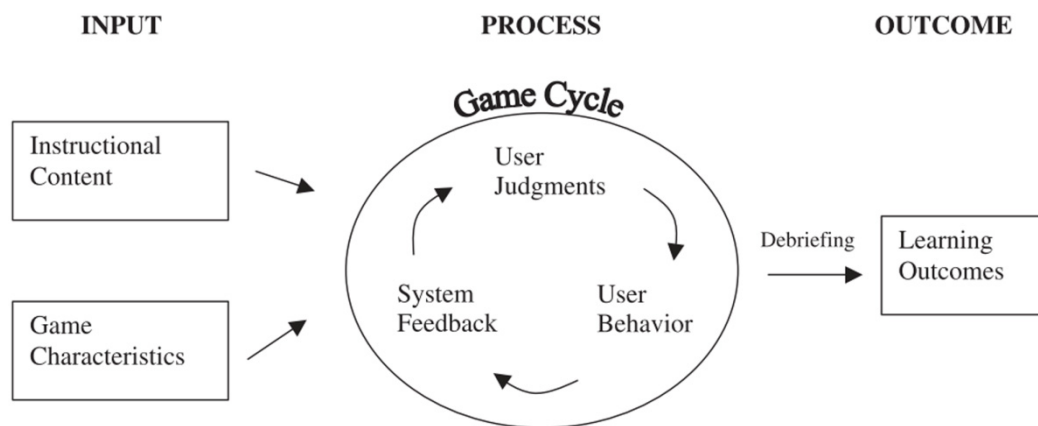


Figure 2.6 - Garriss (2002) *Input-Process-Outcome Game Model*

This is a high level view of the interaction that happens within a gameplay setting. Although Garriss draws upon Flow theory to examine the nature of motivation in this model, she does not go so far as to directly apply her findings to actual design properties that would instigate Flow within the game process. However, she does 'conclude that game characteristics can be described in terms of six broad dimensions or categories: fantasy, rules/goals, sensory stimuli, challenge, mystery, and control'. These dimensions do have relevance in the description and analysis of games in general terms. They aid in forming a framework which translates educational topics into Flow inducing gameplay, but they do not lay out how that should be done.

### *Game Object Model*

On the opposite scale from IPOG is GOM, or Game Object Model vII by Amory, (2006) revised from Amory and Seagram (2003) (see Fig. 2.7). This model is based on the Object Oriented Programming System paradigm which they describe as allowing development and analysis of complicated designs, and facilitating understanding of complex situations.

In GOM vII we see a combination of Objects such as Game Space, Visualisation Space, Problem Space and the Social Space. These interact with other internal object spaces which allow the model to describe

the elements that make up an educational game while showing how a player interacts with that game. Each 'Object' then leads to both 'Abstract' (closed circle) and 'Concrete' (open circle) interfaces. The Abstract interfaces refer to pedagogical and theoretical constructs and the Concrete interface to game design elements.

The model is founded upon solid research theories from multiple sources and includes the application of Flow theory. However, unlike previous models, it directly attributes these theories to game design features such as story, plot, graphics, sound, etc. So it offers a comprehensive, albeit higher level, method for linking educational theory to game design and development.

Where it appears to fall short is in a lack of an 'Object' which handles the interpretation of pre-game learning outcomes into the game space. As with the other models, it also stops short of providing a practical design process that can be utilised directly in development of a full game project. Amory, by his own admission, states the GOM II 'provides a theoretical basis for the design of educational games'.

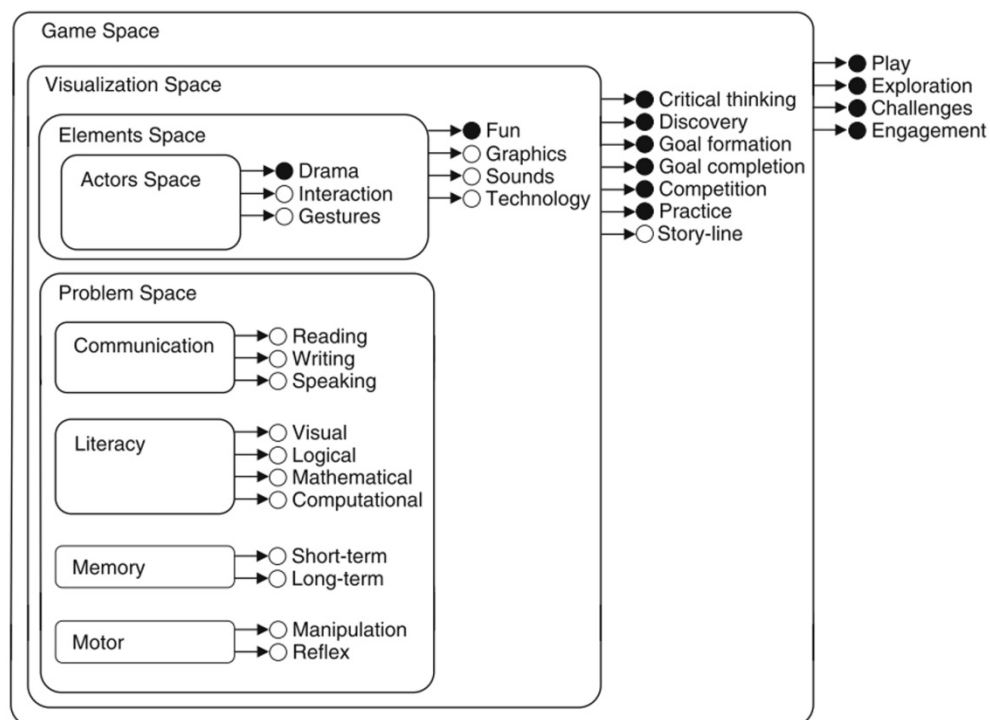


Figure 2.7 - Game object model version II (Core concepts: 1, Game definition; 2, authentic learning; 3, narrative; 4, gender; 5, social collaboration; 6, challenges-puzzles-quests)

### 2.1.4 Assessment Instruments

To measure the impacts of serious games and aid the valuation of engagement within educational games, this section reviews some of the assessment instruments and methods that researchers are currently drawing upon. As was noted in section 2.1.2, there is a need for further empirical evidence (Connolly et al., 2012; Girard et al., 2013; O’Neil et al., 2005) to not only support the learning value of games, but to also measure their value in terms of motivation and immersion. As the review of literature has revealed, Flow emerged as a preferred method for describing not only the nature of the motivating gameplay experience, but also as a tool for guiding design of games.

Sweetser & Wyeth, (2005) built upon the notation of gameflow as described by Salen & Zimmerman, (2004) and developed a model for evaluating player enjoyment in games termed GameFlow. Their GameFlow model draws together the various heuristics into a concise model of enjoyment structured by Flow, thus enabling the review of player enjoyment in games. The GameFlow model recommends the evaluation of all aspects pertaining to Flow, such as; challenge, clear goals, and feedback; but with the inclusion of social interaction.

The gameflow concept and subsequent GameFlow model spawned additional assessment methods that allow the assessment of motivation, engagement and immersion in gameplay. These additional methods are Pervasive GameFlow (Jegers, 2007), RTS-GameFlow (Ding, Tang, Lin, & Zhao, 2009) and EGameFlow (Fu et al., 2009). Each of these methods build directly on the GameFlow model, but in subtly differing ways.

Pervasive Gameflow focuses on entertainment based games and defines pervasiveness in three ways; (1) mobile/place-independent gameplay, (2) social interaction between players, and (3) integration of the physical and virtual worlds. This pervasive focus makes it less relevant to the assessment of serious games in the research context of this thesis. The RTS-GameFlow method is again developed directly from the GameFlow model, but with a focus on one genre or playing style of game, therefore it is less generalisable. Ding et al. also offers no clarity on the method of assessment post gameplay. The most generalisable of the models is Fu et al.’s EGameFlow, which not only builds upon Sweetser’s model, but is also defined as ‘a scale to measure learners’ enjoyment of e-learning games’ in particular. They provide a table of validated statements that can be used in a questionnaire to directly assess a player experience post play. It is this measure that is most useful in measuring the impact of a game’s design post-play.

Wiebe et al., (2014) propose the User Engagement Scale (UES); a flow based assessment measure that builds upon Jackson & Marsh's (1996) Flow State Scale (FSS). They propose the UES scale as a psychometric tool to measure engagement during video gameplay. They find that the UES and its variant the UESz to be more predictive of game performance than the FSS. At this point it appears that the UES is at an early stage and would benefit from application in additional studies to improve its validity.

There are two non-flow based assessment measures that assess games from a perspective other than pure player enjoyment. These have been developed by Dunwell et al., (2012) for assessment during gameplay, and Hong, et al. (2009). Dunwell introduces a framework for externalising the process of assessment in a serious game through the use of in-game achievements and feedback from an assessment engine. This is a very specific set of measures that must be built into the gameplay from the outset, and is therefore not a method that can be easily used by other researchers as a simple post-gameplay measure.

Hong however, developed a more general assessment tool that aims to examine the educational values of digital games. They sorted evaluation indices into seven categories: (1) mental change, (2) emotional fulfilment, (3) knowledge enhancement, (4) thinking skill development, (5) interpersonal skill development, (6) spatial ability development, and (7) bodily coordination. They state that their research provides a preliminary framework for future game designers, and parents and teachers, in assessing educational values of digital games. Their research, like the EGameFlow, provides a measurement questionnaire that covers their categories.

A point raised by Bellotti, (2013) confirms the findings of earlier reviews of O'Neil et al., (2005), that empirical evidence is lacking and that learning outcomes in serious games are under studied. However, there is extensive research and publications that outline how educational objectives can be supported through the development and assessment of learning outcomes.

This section discusses a range of assessment methods and instruments that can provide methods for assessment which highlight properties of game design. These instruments can be used to measure levels of motivation through GameFlow and to capture more general gameplay indices. As a means to provide more empirical evidence of the educational value of games we discussed educational practice in the form of learning outcomes. As this thesis is focused on game design and development, both

gameflow and learning outcomes contribute by informing the research with design and assessment methods.

## **2.2 Discussion**

Evaluation of the literature reveals a consensus that computer games can provide effective learning experiences, although there is a need for additional empirical evidence to support this. Understanding motivation conditions appear as seemingly fundamental to the analysis, design and development of educational games. Of the literature and game models reviewed, enjoyment and motivation in educational games were repeatedly described in terms of entering a Flow state. Design elements are also mentioned as important, as were narrative context, interactivity, rules, goals, rewards, feedback and challenge.

From a perspective of learning and knowledge acquisition there appears to be a general call for more emphases on experimental methods (Connolly, et al., 2012; Girard, et al., 2013; O'Neil, et al., 2005; Wouters, et al. 2013). This includes using the pre/post method and a call for more studies that include control groups to compare the educational performance of serious games to more traditional teaching approaches. In terms of inferring how conditions can converge to generate a motivating experience, it appears that the more reliable and validated methods are born out of Flow theory. Flow's eight conditions of an optimal experience are an indicator of the emergence of intrinsic motivation. The concept of Gameflow have been presented by several researchers (Fu, et al. 2009; Salen and Zimmerman, 2004; Sweetser and Wyeth, 2005) which is a combination of Flow conditions and game heuristics. Gameflow is found to be a useful construct in the assessing and measuring of the Flow experience within gameplay. Keller & Bless's, (2008) work on Flow and regulatory compatibility find support for conditions of Flow to act on levels of intrinsic motivation especially between the fit of skills and task demand.

For a deeper understanding of knowledge acquisition in educational games there is a need for more analysis and study of learning outcomes. In general, if the gameplays' intended learning outcomes are not known it would be challenging to undertake experimental studies that assessed the level of knowledge acquisition the game imparts. Therefore, we are of the opinion that gameplay must be, to some degree, framed around the notion of learning outcomes and objectives. These are established features of educational practice illustrated in the use of the SOLO taxonomy (Biggs & Collis, 1982) and articulated by (Allan, 2006).

The practice of defining learning outcomes can bring an approach to educational game design that addresses some of the criticisms of the educational game studies reviewed in this chapter. As learning outcomes brings a structure to the learning that allows for measurement of skill learning, within the gameplay, they can then be assessed through empirical studies (Bellotti, et al., 2013; Connolly et al., 2012; Dondlinger, 2007; Garris, et al., 2002; Linehan, et al., 2011; O’Neil et al., 2005; Wei & Li, 2010).

Motivation within gameplay is a significant factor that is stressed by many of the research studies (Aguilera & Méndiz, 2003; Bellotti et al., 2013; Boyle et al., 2011; Dondlinger, 2007), design models (Cowley, et al., 2006; Kiili, 2005; Wei and Li, 2010) and assessment instruments (Fu et al., 2009; Sweetser and Wyeth, 2005; Wiebe, et al., 2014). So alongside the need for learning outcomes, a thorough understanding of the nature of motivation, in relation to educational gameplay, is recognised in the body of research work contained in this thesis.

In terms of education game design, the literature reveals that the application of theory, into practise, is desired to advance the field. This includes clear steps for implementation that go beyond analysis and evaluation, and brings together motivation, skill learning, learning outcomes, and design and production. Our main criticism of the current design practise and resulting models, is a tendency to focus on the theory behind educational game design, while falling short of directly addressing the practical implementation of design from the production and development viewpoint of the designer.

This thesis approaches the educational gaming debate from a designers perspective. It presents research that provides clear steps for design and production methods, with a focus on bringing together motivation, skill learning, and learning outcomes.

### ***2.3 Structural Playability; an Approach to Game Design***

The author has worked within the field of game design and education for a number of years; undertaking a Master of Arts in Design (Strategy and Innovation) with a specialisation in computer game playability design. This was followed by teaching in higher education as a senior lecturer within the field of creative technology, again with a specialism in computer game design and development. During this time the author contributed to the field of educational game design through the development of a Structural Playability Design (SPD) model for game design.

The alignment of skilled performance theory to support game design was developed and tested by the author in support of a Master of Arts in Design, The Structural Playability Design model was first presented at the 2nd International Learning with Games Conference in 2007 (Bradshaw, 2007). The MA

research provides the initial design model and starting point of this PhD research. This section describes the development of the SPD model in more detail, providing the background to the Structural Playability Process (SPP) model presented in Chapter 3. The premise of the Master's thesis was;

*'that designing computer game 'playability' by applying psychological principles can enhance the enjoyment and effectiveness of the player experience, while aiding the game developer in the design process' (Bradshaw, 2007).*

### 2.3.1 Skilled Performance Theory and Game Design

Human Performance is a field dedicated to understanding how we as human beings have acquired the skills that have helped us to survive and adapt to our environment throughout the course of history. In this field Fitts & Posner (1967) p3 state, 'we learn through acquiring skills and skilled performance always involves organised sequences of activities. Organisation, goal directedness and utilisation of feedback are basic characteristics of a skilled performance'. They see learning in terms of the modification of existing skills and describe learning as 'a relatively permanent change in performance that can be shown to be the result of experience' p8.

The basis of any computer game is a scenario where the player is asked to go through a series of goal related tasks where they have to learn and adapt skills. In real life, learning skills means continued survival; in a computer game it means achieving the game outcome. If we assume these concepts are the same, for both real and virtual worlds, we can apply the same set of rules from real environments to artificial environments.

By understanding the conditions of Skilled Performance we can begin to create artificial environments maximised for player reward and fulfilment. These designed environments can provide goal directed skilled behaviour, through task based sequential activity within a system of feedback and rewards. For example in the online game *World of Warcraft (WoW)*<sup>3</sup> one of the many goals of the player is becoming a 'Master' of a profession such as leatherworking. By undertaking a sequence of skill based tasks the player slowly 'levels up' their skill, resulting in an improvement to their character's ability to operate in the game world. It is this skill learning capability of games that can be harnessed for educational gameplay.

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<sup>3</sup> <http://us.battle.net/wow/en/profession/leatherworking>

Through investigation into Human Performance theory, Fitts & Posner, (1967) p1-3 & p8-15, describe firstly the features of a skilled performance, which can be summarised in four distinct principles and three Phases of skill Learning.

The four features of a skilled performance are:

- (1) Skilled performance always involves an organised sequence of activities,
- (2) Skilled behaviour is goal directed,
- (3) The full complexity of sequential activity can seldom be understood except when the end objective or goal is also understood,
- (4) Each act is dependent upon comparison of what they think is desired, either through feedback (external stimuli) or comparison of progress towards a goal.

The three phases of skill learning are, as Fitts and Posner state ‘a hierarchical and sequential organisation of skills’ with one phase merging gradually into another. These are; (1) Cognitive, (2) Associative and (3) Autonomous. When the four basic principles aiding a skilled performance are actively applied in a learning environment and a skilled task is undertaken, then the environment is setup to enable a skilled performance.

The body of the master’s research concentrated on the translation of the skilled performance principles into gameplay parameters. These were formed into a design model for mapping the structure of playability for the purpose of developing engaging, skill-driven gameplay. The theory of structural playability was tested through the design and development of a computer game titled ‘Rasputin’ (Fig 2.8) and subsequently published in two articles (Bradshaw, 2004, 2007).



Figure 2.8 - Screenshots from the ‘Rasputin’ computer game

The following two sections provide an overview of the master’s research outcomes that link the nature of the two aspects of skill performance to gameplay principles that can be applied to the design for learning-gameplay; (i) the four playability principles and (ii) three phases of skill learning.



### 2.3.1.1 The Four Principles of a Skilled Performance:

Fitts & Posner's (1967) principles of a skilled performance are listed first and their optimisation for learning-gameplay experience follow.

1. Skilled performance always involves an organised sequence of activities.
  - **Structural principle** – A logical gameplay structure forms the best experience for skilled performance.
2. Skilled behaviour is goal directed.
  - **Goal principle** – Any task that requires some skill has to aid you in the attainment of your goal.
3. The full complexity of a sequential activity can seldom be understood except when the end objective or goal is also understood.
  - **Clarity principle** – Make the goal clear to your player from the start of the task, so they can understand why they are undertaking the task.
4. Each act is dependent upon comparison of what they think is desired, either through feedback (external stimuli) or comparison of progress towards a goal.
  - **Comparison principle** - The player needs a (visual, tactile, audible) response to their actions to be able to compare how well they are doing in relation to their desired outcome, or alternatively the player needs to know how their actions have progressed them towards attainment of their goal.

### 2.3.1.2 Three Phases of Skill Learning

According to Fitts & Posner the learner acquires the skills required of them by passing through the three Phases of Skill Learning; (1) Cognitive, (2) Associative and (3) Autonomous phases. Schmidt & Lee, (2005) recognise the phases of skill learning as characteristics of the learning process. They draw on “the three-phase (or stage) view of learning suggested by Fitts (1964, Fitts & Posner 1967) and later Anderson (1982, 1995)”. Schmidt & Lee utilise this theory when describing real world physical action and reaction. Our research attempts to apply this theory cognitively to understand player reaction within a game-world, and by designing gameplay that supports the players’ journey through each skill phase, the probability of a successful interaction with that environment is increased and subsequently the learning experience improved. The Phases of Skill Learning are also described under the terms ‘cognitive skill acquisition’ (VanLehn, 1996) or ‘cognitive procedural learning’ (Beaunieux et al., 2006) but their composition is the same.

The following text outlines the three phases of skill learning and gives examples of where they might occur in gameplay design:

### 1. Early or Cognitive phase:

This is where a learner tries to understand the task and what is being demanded of them.

- A good instructor calls attention to the perceptual cues, response characteristics and gives diagnostic knowledge of results. Behaviour can be shaped by affirming sequences of acts that resemble the correct one (positive feedback)

In gameplay this could be a tutorial level or on screen instructions. The player would be able to call upon these elements until completion of the task, as removal would be frustrating and unrewarding for player progression.

### 2. Intermediate or Associative phase:

In this phase new patterns of skill are utilised that are based on the skills learnt in the cognitive phase, producing a marked reduction in significant mistakes.

- Frequent rest periods will facilitate performance, especially in motor skills as lack of muscle rest creates incorrect practice as muscles tire.
- If the task is too complex to practice as a whole then practice its separate components.

In gameplay, choose items that are nearly independent of each other and alternate between practising the item and the whole task. Players can practise individual skills such as jumping while still progressing in attainment of the overall goal. Cut scenes make good rest periods alongside other simpler activities drawing upon skills already learnt.

### 3. Final or Autonomous phase:

The skills learnt become increasingly automatic.

- The learner thinks less about what they do and outside stimulus has less affect.

In gaming the player needs less direction in the gameplay mechanics and new, more challenging skills and environments can be introduced. Combine tasks when learning a skill at this stage. If one task has a level of predictability it can be learnt in combination with another task and both will see improvement. For example, this can be seen in a player's ability to combine a jump, punch and kick into one move in aid of a new task.

These phases are parallel in their similarity to stages of difficulty in gameplay. They can be applied to the start and end of a playing level or encompass the complete game strategy. They can also be contained as elements within themselves as subsets within the greater game concept. The key is not to miss out a phase or its key-elements as the learning experience will

lose optimisation. Working with these phases as a guide when designing a computer game concept, level or module should enable creation of a platform for effective learning gameplay.

The result of this work was the development of a conceptual design process entitled the Structural Playability Design (SPD) model.

### **2.3.2 Introduction to the Structural Playability Design Model (SPD)**

The term Structural playability is used to describe how conditions for creating a skilled performance are used to structure the gameplay design to provide an effective playability within the game. It followed on from the Structural principle, which calls for gameplay to provide a logical structure that forms the best experience for creating a skilled performance.

The result of the research was the development of a model that maps the elements of Skilled Performance in the context of game design.

In this section we provide a step-by-step guide to understanding the model. The model is, broken down into three stages; 1) High Concept Development, 2) Gameplay development and 3) Production.

To view the model, see Fig. 2.15 at the end of this section.

**1. Stage 1 - High concept development** comprises of 2 sections:

- A) Progression revision
- B) Skill Phase development

**Section A** – progression revision has 2 parts:

### 1) Narrative Input:

Governed by the **Structural principle**: a logical gameplay structure forms the best experience for skilled performance, as it provides an organised sequence of activities, see Fig 2.9.

- Narrative Input comprises of:
  - **A – Context**; define the learning outcomes so they can be embedded in the narrative.  
The designer asks: **What** are the roles and goals of the player?

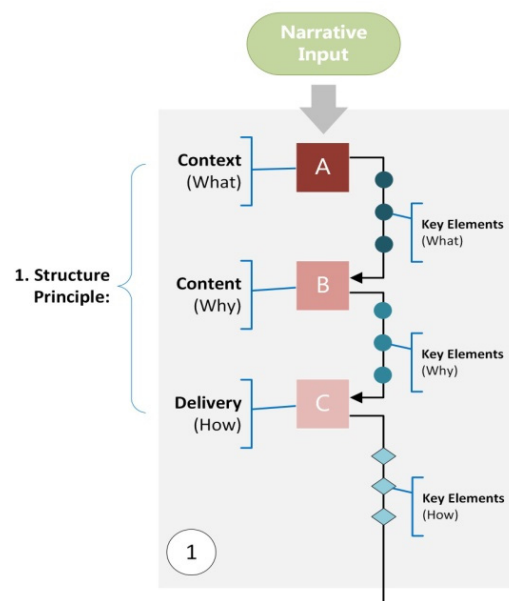


Figure 2.9 - Section A – 1) Narrative Input

- **B – Content**; of the game devised from the players role and goals.

The designer asks: **Why** is the player doing what they are doing, is it a logical sequence?

- **C – Delivery**; what can the player expect to interact with during gameplay?  
The designer asks: **How** will the content be delivered as game mechanics? Game mechanics being the mechanisms that provide and support player interaction with the gameplay.

The outputs from these 'sorting' questions are the '**Key Elements**' that form the gameplay basis. The Key Elements breakdown the gameplays' goals into skilled tasks that can be translated into gameplay missions. They are the mechanics of the game that enable mission completion.

### 2) Narrative Progression:

Governed by the **Goal principle**: any task that requires some skill has to aid the player in the attainment of the local and/or overall goal. The primary function here is to define the end goal of the gameplay narrative, enabling the designer to start the process of setting in place the key-elements of the narrative which act together to form the learning chain of skills and tasks.

- Narrative Input leads to the ‘Narrative Progression’ timeline. This is comprised of ‘Narrative events’ that are based on the Why and How decisions made in the design when considering Context, Content and Delivery. (Fig 2.10)
  - Why events are ‘Progression events’ – these are items that push the gameplay forward. These help the designer define the gameplay missions which house the task based skills to be undertaken by the player.
  - How events are ‘Components events’ – they are the linked game mechanics

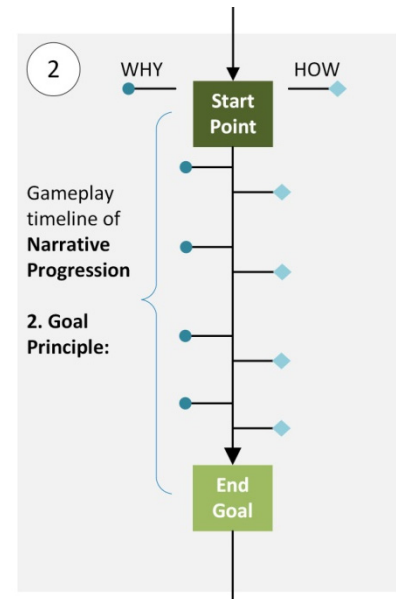


Figure 2.10 - Section A – 2) Narrative Progression

A component event (mechanic) defines how a Progression event is experienced by the player, in the game world. Progression and Component events create the basis of a logical ladder of skills and tasks; progressing the player in achieving the end goal/learning outcome.

### Section B – Skill Phase development

Here the information generated in the Progression Revision section A, is formed into gameplay levels. But first the gameplays’ narrative progression events are explored within the framework of the Fitts & Posner's (1967) three phases of skill learning. The phases move from cognitive to autonomous as the narrative of the gameplay progresses. As shown in Fig 2.11 the gameplay elements are divided

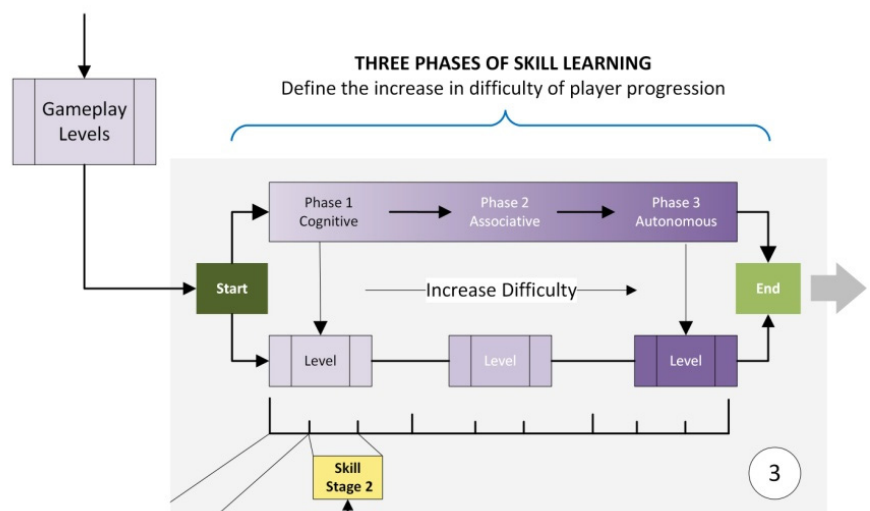


Figure 2.11 - Section B – Skill Phase Development

into levels that increase in difficulty. Appropriate challenges are applied that match the players’ pace of learning most relevant to the current skill phase. The gameplay levels are further broken down into Skill Stages, where goal directed skill based tasks form the basis of the gameplay delivery.

## Stage 2 – Gameplay Development

Where the skill stages are mapped from the gameplay levels, see Fig. 2.12.

- **Section C – Skill Stage Mapping**

Skill stages have several components that work together to teach a skill, with the intention of progressing the gameplay. The final two Skilled Performance principles, **Clarity** and **Comparison** govern design decisions, see Fig 2.12.

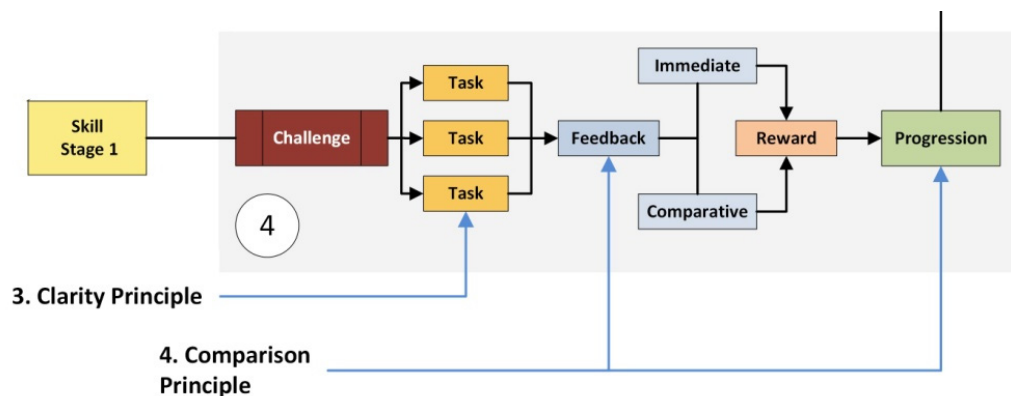


Figure 2.12 - Section C – Skill Stage Mapping

- **Challenge** forms the basis for the skill stage and leads to as many tasks as required to meet the challenge
- **Tasks** are governed by the **Clarity principle**:
  - Make the goal clear to your player from the start of the task, so they can understand why they are undertaking the tasks and how it meets the challenge
- Feedback is received during and after tasks. And is governed by the **Comparison principle**:
  - The player needs a (visual, tactile or audible) response to their actions, to be able to compare how well they are progressing in relation to the desired outcome, or alternatively the player needs to know how their actions have progressed them in attainment of the level/game goal.

- The designer plans for two types of feedback, Immediate and comparable. These lead to a reward which can also act as a form of feedback, and as a reinforcement mechanism in the skill learning.
- **Progression** is the final step in this mapping and is the point where the skill stage has been completed and the player is capable of advancing to the next skill stage/level or Skill phase depending on where they are in narrative.

### Stage 3 – Production

When the game design has a mapped gameplay structure the next stage is to implement the design.

- **Section D – Engine Development**

Here the designer has the task of working with a production team to realise the various elements of the gameplay. Up to this point the majority of the design has been theoretical, with perhaps some prototyping exploring some of the specific mechanics achieved. (Fig. 2.13)

- Production requires a team with a core roles in coding, art and audio with a test protocol to provide quality assurance (QA)

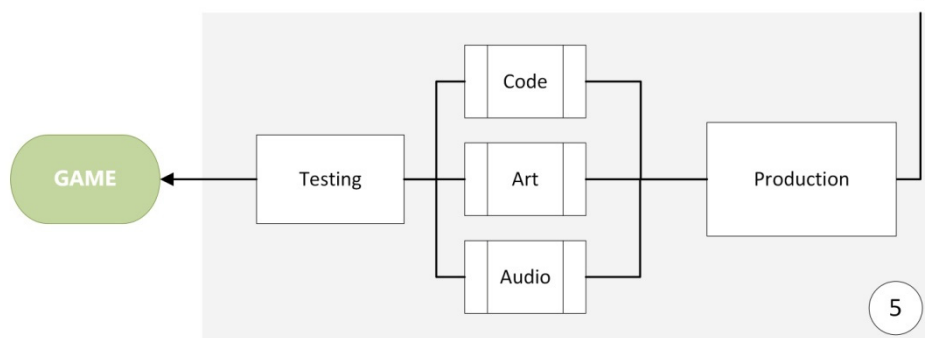


Figure 2.13 - Section D – Engine Development

Figure 2.14 illustrates how the SPD model informed the design of the game 'Rasputin'. It shows the structure of the skill stages that house the tasks and rewards of the gameplay, which are defined by the difficulty levels that follow the three phases of skill learning. It employs a simple narrative; Rasputin's is trying to gatecrash a party at the Kremlin and throughout the gameplay has to overcome obstacles that stop him reaching his destination. To reach the Kremlin he has to get from the bottom of the gameplay screen to the top by jumping through moving holes in the platforms above his head. The players' job is to successfully navigate to the top of the screen so Rasputin can reach the next level. The further Rasputin progresses the more difficult it is for him to reach his goal. All the while this simple gameplay is measured against the four principles of a skilled performance, by setting clear goals, that follow a logical

sequence of tasks, providing feedback, level rewards and a final score table to measure improvement in performance.

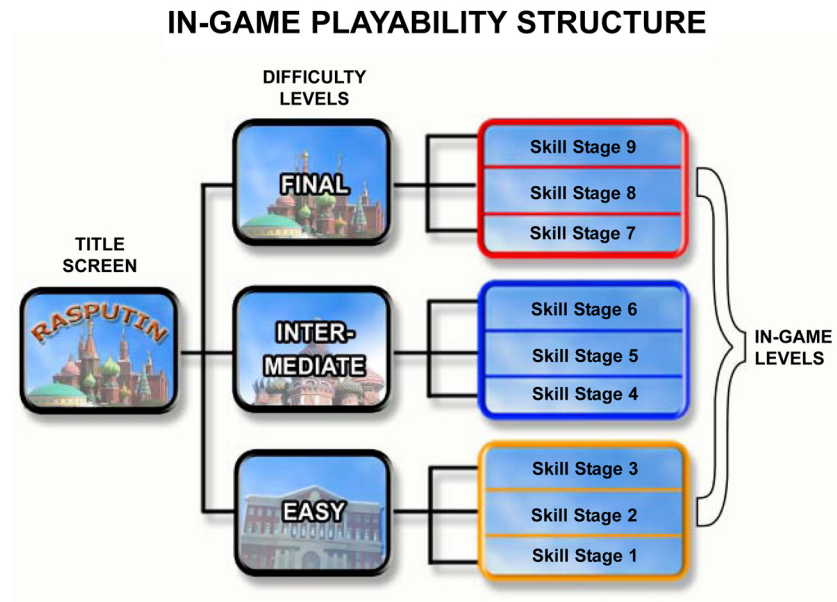


Figure 2.14 - The in-game playability structure of 'Rasputin' built from the SPD model

The full layout of the SPD model can be viewed in Fig 2.15. This model shows the areas of design already established during the earlier Master's research. As can be seen Section D of the model is mainly unexplored and provides the greatest opportunity for further research. The earlier work explored the game design process, but didn't extend this into game production. The model at this stage is a theoretical exploration of how to apply skilled performance principles in game design.



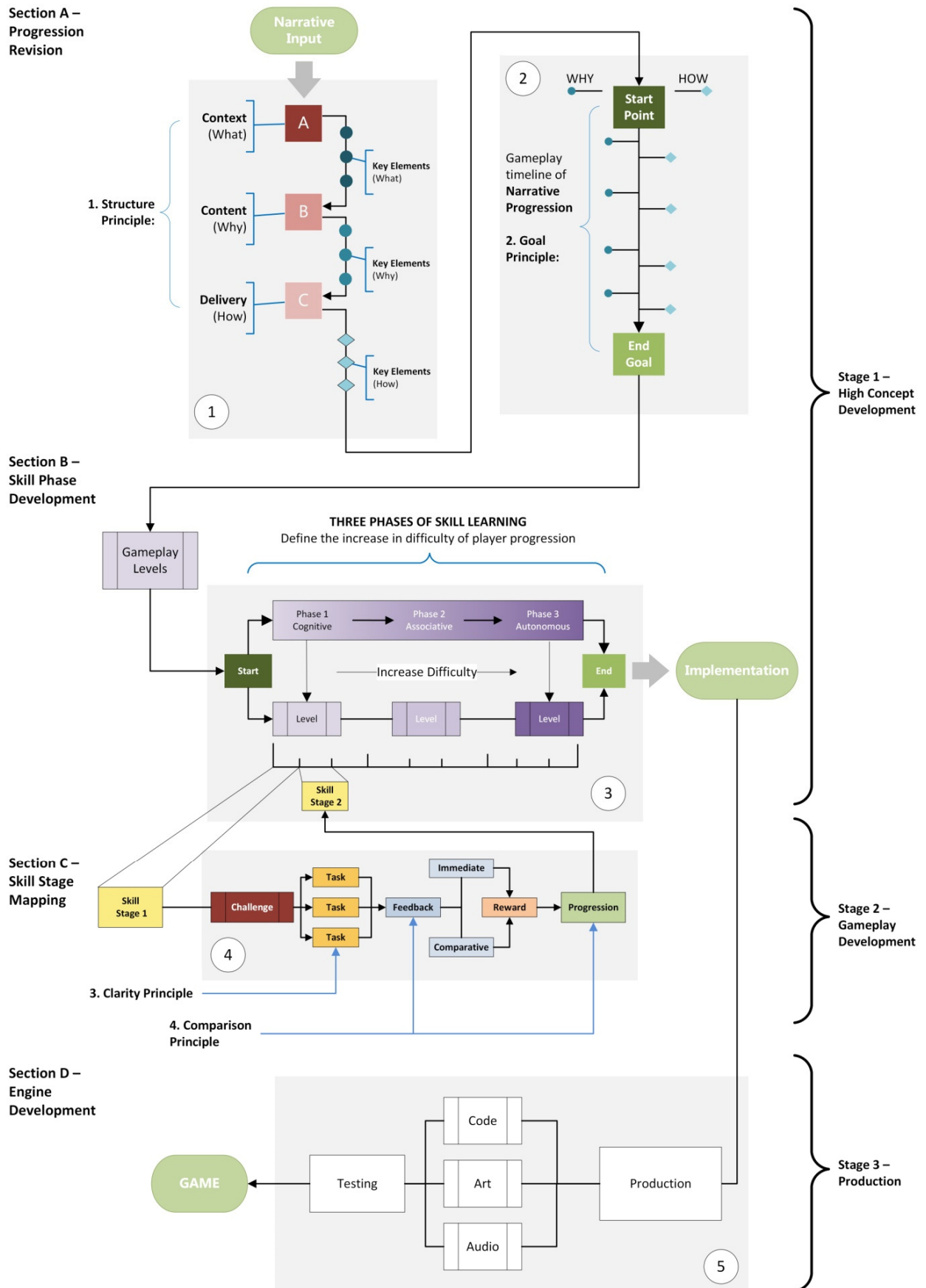


Figure 2.15 - The complete Structural Playability Design (SPD) model

In Summary, the focus of research is in addressing the gap in practical game design approaches that guide the factors of motivation and structured learning outcomes, with the intention of answering the research question;

***What is an effective design process for computer games that deliver structured learning activities?***

The next chapter will outline the approach that was undertaken in the realisation of this doctoral research. It builds upon the findings of the review of literature in this chapter and brings a new model for educational game design that is built upon the SPD model presented here.

# 3

## The Approach

This chapter will present the Structural Playability Process (SPP) as a practical design approach to building learning games. It will introduce the learning theories that combine to create this process and explore how those theories are combined. It will then present the SPP approach as a practical design model before providing an in-depth exploration of the design stages. We then propose the research strategy for the testing the SPP through the development of two computer games. The SPP builds upon the theoretical framework of the SPD model, introduced in chapter 2.

The SPP is the major theoretical contribution of this PhD work and provides one of the first practical design processes for building learning games. It is unique in that it breaks down the design of an educational game project into simple design and implementation oriented steps. The SPP has the following advantages in that it links learning theory to practical design steps, it addresses the game project from early concept idea right through to the in-engine gameplay mapping, and it does this in terms that can be understood by a range of project stakeholders, from the client to the game programmer. It also applies the theory of Skilled Performance to game design, and as such it introduces a new theory to the field of educational game design.

### ***3.1 Learning Theories and their Relationship with Game Design***

As seen in the previous chapter there are several theories in psychology that are pertinent to this research. These are the Skilled Performance theory put forward by Fitts & Posner, (1967) in their work on Human Performance, the motivational theories of Maslow, (1943) who suggested that growth and self-actualisation of the personality, being a lifelong process, can be driven by learning, Deci & Ryan, (1985) who see motivation in the form of self-determination, and the work of Csikszentmihalyi, (1990) on optimal experience termed as 'Flow'. It was found in the literature review that numerous models of educational game design applied the characteristics' of Flow in their structure.

These theories can be connected together in computer games. Theoretically, the development of computer games which create Csikszentmihalyi's conditions for 'Flow' in a learning experience

(Oblinger, 2006; Prensky, 2003) can produce 'intrinsic motivation' (Deci & Ryan, 1985). Thus driving the player to take on further challenges and as a consequence drive learning.

We'll address each of these theories in turn, exploring how they can be integrated into a process that attempts to embed learning outcomes within the design of engaging computer gameplay.

### **3.1.1 Learning Outcomes**

From an educational standpoint, learning outcomes and objectives can be seen through the lens of 'outcome-based education' (OBE). Spady, (1984) describes this as 'clearly focusing and organizing everything in an educational system around what is essential for all students to be able to do successfully at the end of their learning experiences'. Biggs & Collis, (1982); Biggs, (2003) propose the SOLO taxonomy (Structure of the Observed Learning Outcome), which is a systematic way of describing the growth of complexity of a learner's performance in mastering academic tasks. This taxonomy can be used to define objectives, describe where students should be operating, and evaluate learning outcomes.

Learning outcomes and objectives have a long history within educational practice, and Allan, (1996) provides a thorough review of their history in higher educational practice. She concludes that the process of defining and expressing learning outcomes should enable lecturers to reflect upon what they intend their students to learn, and thereby 'articulate the relationship between what they teach and what students do, in fact, learn'.

### **3.1.2 Motivation Theory and Game Design**

One of the reasons for looking at skilled performance is its ability to provide a starting framework on which to scaffold gameplay interactions. However, a scaffold only provides support for the gameplay narrative without providing us with the tools to craft a narrative that a player wishes to engage with.

If we are taking an educational perspective then we need to craft learning outcomes that have a chance of being engaged with by our intended audience. From the examples provided in the literature review (Aguilera & Méndiz, 2003; Connolly, et al., 2012; Dondlinger, 2007; Wei & Li, 2010) we began to investigate the nature of motivation and how we could provide motivational qualities to further develop the SPP approach.

Maslow's (1999) work took the study of motivation beyond the realm of drive based needs and began to see motivation as 'self-actualisation'. When we as human-beings are able to satisfy our basic survival needs we are able to apply ourselves to other concerns. Self-actualisation is that desire for self-fulfilment. Maslow presented us with what he termed the hierarchy of needs (see Fig. 3.1). Maslow saw human needs

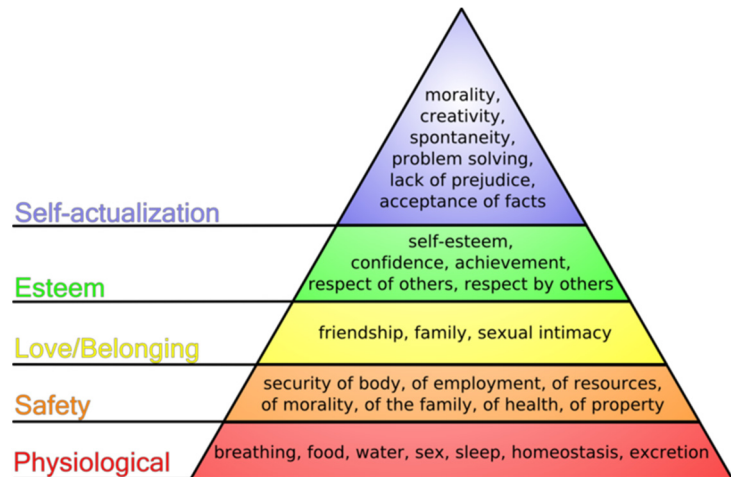


Figure 3.1 - Maslow's Hierarchy of Needs

as grouped in deficiency needs and growth needs. Deficiency needs are Physiological, Safety, Love/belonging and Esteem. Each need must be met in turn before the individual can move on to the next level. If at some point in the future a 'deficiency' in one of the areas occurs then the individual will attempt to rebalance. According to Maslow when all of the deficiency needs are met the person is able to act upon the growth needs that comprise Self-Actualisation. Such needs are morality, creativity and spontaneity, etc. Only then is the individual motivated to self-actualise and experience what Maslow termed 'peak performance'.

Deci & Ryan, (1985) present an organismic theory of Human Motivation that provides insight on the motivating conditions that drive the transition between the different levels in the 'Hierarchy of Needs'. They propose that self-determination is necessary for an individual to become intrinsically motivated. Self-determination occurs when an individual experiences 'freedom in initiating one's behaviour' or in other words freedom from control. They find that the concept of self-actualisation is descriptively useful for positive correlation with autonomy and negative correlation for control. But it is not just freedom from control alone that provides a basis for self-determination. It is also the ability to experience a degree of control over an environment.

*To be self-determining one must have the skills to manage various elements of one's environment, otherwise one is likely to be controlled by them... people have a need to experience control over their environment or their outcomes'. Deci & Ryan, (1985) p30*

Intrinsically motivated activity is based in the need for self-determination. To be intrinsically motivated the individual acts on drives that come from within themselves occurring when desire and interest have no external force or pressure. To become intrinsically motivated action is experienced as autonomous,

which refers to the experience of freedom in initiating one's own behaviour, put simply to have a choice. This state of autonomy is also present in skilled performance in the third phase of skill learning where 'the skills learnt become increasingly automatic and the learner thinks less about what they do and outside stimulus has less affect.' Furthermore intrinsic motivation is 'unlikely to function under conditions where controls or reinforcements are the experienced course of action' (Deci & Ryan, p29 1985). Given such a basis it is unsurprising that classroom based teaching can feel so demotivating as the student can experience limited to no control or autonomy.

*'Deci (1980) suggested that the intrinsic need that was operative for subjects in the various control studies was not a need to control the environment, but rather a need to be self-determining that is to have a choice' (Deci & Ryan, p31 1985)*

In terms of gameplay, designers refer to a concept termed the 'illusion of choice'<sup>4</sup>, where the player is given the option to explore different 'choices' which ultimately lead to the achievement of a predetermined gameplay goal. Good game design should allow the player to find their own route to the goal. Even if that route is not the most effective or efficient it may well be the most enjoyable.

Deci and Ryan further propose that, 'the intrinsic needs for competence and self-determination motivate an ongoing process of seeking and attempting to conquer optimal challenges'. Understanding player motivations to provide a self-determined experience informs the gameplay challenges. Skilled Performance conditions can then set the pacing of the challenges building a foundation that can then support Csikszentmihalyi's (1990) Flow conditions.

To create conditions of a Skilled Performance an increase in difficulty, i.e. the difficulty of the challenges, is required as the learner moves through the three 'Phases of Skill Learning'. The pacing that Skilled Performance brings, links to Flow generation, as they share a need for appropriately balanced challenges to ensure continued motivation. In Flow challenge has to increase at an even rate to skill to avoid the subject becoming bored or anxious, both of which will quickly lead to disengagement and demotivation.

Intrinsically motivated behaviour occurs in individuals who approach activities that interest them. So in any game design scenario knowing the interests of your demographic group and building the design challenges from their perspective will provide the most effective chance of producing intrinsic motivation and continued engagement.

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<sup>4</sup> <http://www.penny-arcade.com/patv/episode/the-illusion-of-choice>

*The antithesis of interest and flow is pressure and tension. Some degree of extrinsic motivation is involved i.e. deadlines, material gain... Extrinsic motivation refers to behaviour where the reason for doing it is something other than an interest in the activity itself' (Deci & Ryan, 1985 p35).*

In game design extrinsic motivation can be used in the form of short-term goal reward, for example through the acquiring of points or in-game money. This provides immediate reward to players as a source of extrinsic motivation. This aids the player by supporting further interaction with intrinsically motivated rewards of the game, which tend to be more long-term in nature.

A firm theoretical basis can be established to define effective learning outcomes and practical game mechanics, by utilising Deci & Ryan's, (1985) organismic theory of Human Motivation, in conjunction with the practical aspects of Skilled performance and the enjoyment consequences of optimal experience (Flow). By understanding player motivations, the path to achieving the learning outcomes can be tailored to meet the intrinsic needs of the player through provision of self-determining gameplay. Application of Skilled Performance conditions provides the pacing of the self-determined gameplay. It paces the degree of difficulty of the learning challenges, which in turn provides the balance between anxiety and boredom that motivates the continued interaction and promotes the conditions required for achieving a state of Flow.

### **3.1.3 Flow Theory and Game Design**

In this section we will provide an overview of Flow theory before providing an in-depth analysis of the associations between the scaffold use of skilled performance and the relationships to optimal experience (Flow) within the context of game design. This section is based on the authors published work, (Bradshaw, 2010) in support of this thesis.

Csikszentmihalyi's (1990) work on optimal experience or Flow is an attractive theory because it appears to be a common phenomenon found across a wide range of activities and cultures. He asserts that 'optimal experience, and the psychological conditions that make it possible, seem to be the same the world over'. He further describes Flow as autotelic where 'the key element of an optimal experience is that it is an end in itself'. He goes on to say that 'the activity that consumes us becomes intrinsically rewarding'. When undertaking an activity Csikszentmihalyi describes the channel of Flow sitting between levels of anxiety and boredom.

Of Fig. 3.2 Csikszentmihalyi states;

“The two theoretically most important dimensions of the experience, challenges and skills, are represented on the two axes of the diagram. The letter A represents Alex, a boy who is learning to play tennis. The diagram shows Alex at four different points in time. When he first starts playing ( $A_1$ ), Alex has practically no skills, and the only challenge he faces is hitting the ball over the net. This is not a very difficult feat, but Alex is likely to enjoy it because the

difficulty is just right for his rudimentary skills. So at this point he will probably be in Flow. But he cannot stay there long. After a while, if he keeps practising, his skills are bound to improve, and then he will grow bored just hitting the ball over the net ( $A_2$ ). Or it might happen that he meets a more practised opponent, in which case he will realise that there are much harder challenges for him than just lobbing the ball – at that point, he will feel some anxiety ( $A_3$ ) concerning his poor performance.”

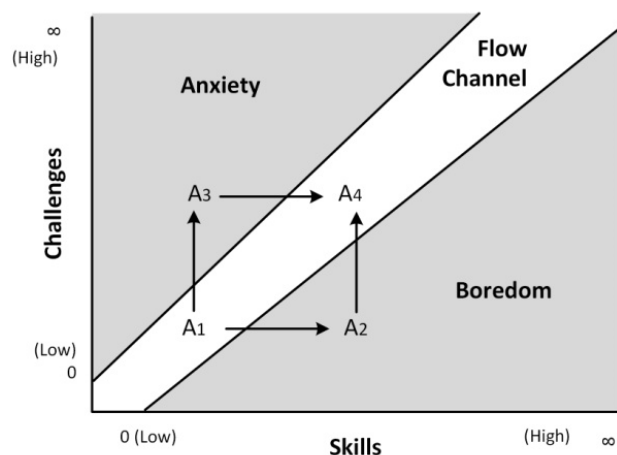


Figure 3.2 - Why the complexity of consciousness increases as a results of flow experiences (Csikszentmihalyi, 1990 p74)

He proposes that it is the balance between challenges and skills that enables the person to attain Flow, motivating them to continue with the activity. Of this Csikszentmihalyi says ‘neither boredom nor anxiety are positive experiences, so Alex will be motivated to return to a Flow state’.

To return to Flow state ( $A^4$ ) Alex will have to ‘increase the challenges he is facing’ by setting a ‘new and more difficult goal that matches his skills’.

Relating this back to motivation as described by Deci and Ryan, the Flow cycle reflects the ‘intrinsic needs for competence and self-determination... to conquer optimal challenges’. It is logical that conquering optimal challenges would lead to the feeling of ‘optimal experience’ that Flow describes. In Skilled performance, it is the ‘Three Phases of Skill Learning’ that bring the structure for pacing challenges in an optimal manner.

Csikszentmihalyi is able to breakdown an optimal experience in to eight conditions which he sees as the elements of enjoyment and motivation. These are listed in Table 3.1.



Table 3.1 – The eight conditions of a Flow state

<b>1. A Challenging Activity That Requires Skills</b>	<i>“The experience usually occurs when we confront tasks we have a chance of completing.</i>
<b>2. The Merging of Action and Awareness</b>	<i>We must be able to concentrate on what we are doing.</i>
<b>3. Clear Goals and Feedback</b>	<i>The concentration is usually possible because the task undertaken has clear goals and provides immediate feedback.</i>
<b>4. Concentration on the Task at Hand</b>	<i>One acts with a deep but effortless involvement that removes from awareness the worries and frustrations of everyday life.</i>
<b>5. The Paradox of Control</b>	<i>Enjoyable experiences allow people to exercise a sense of control over their actions.</i>
<b>6. The Loss of Self-Consciousness</b>	<i>Concern for the self disappears, yet paradoxically the sense of self emerges stronger after the flow experience is over.</i>
<b>7. The Transformation of Time</b>	<i>The sense of the duration of time is altered; hours pass by in minutes, and minutes can stretch-out to seem like hours.”</i>

Csikszentmihalyi suggests that these elements of Flow occur consecutively in an optimal experience and that Flow is experienced in the same way by people across differing activities and cultures. This presents researchers with the theoretical possibility of a universal structure upon which sympathetic game designs can be modelled. Flow has had an important impact on the theory of academic game design. As we saw in the review of literature, Flow has been integrated into a number of game design models from Garriss, Ahlers, & Driskell (2002), Finneran & Zhang (2003), Amory (2006), Kiili (2006) to Cowley, Charles, Black, & Ireland, (2008).

### 3.1.4 Flow, Skilled Performance and Game Design

As previously stated in section 2.2.1, there are four principles underlying a skilled performance (game structure, goals, clarity and comparison through feedback), which then operate within the ‘Three Phases of Skill Learning’. Through analysis of Flow and Skilled Performance, it is hoped that common principles can be identified from both theories which can be used to support a set of measures related to the design and production of games for learning. By understanding and combining related and effective elements from Skilled Performance and Flow, the researcher hopes to develop an approach to game design that not only supports the elements of a skilled performance, but also promotes the conditions for motivation through an enjoyable learning experience. This combination of skilled performance and promotion of motivation conditions is unique to the field of educational game design.

We propose that undertaking a skilled performance starts from the same point as a Flow experience with a skill centred challenge. There are several other Flow conditions to consider if we want to generate a Flow experience. As Csikszentmihalyi indicated, each condition for Flow generates the circumstances for the next. If we design a challenging skilled environment we create the foundation for

action and awareness to merge. This merging happens when attention is completely absorbed by the activity. It is important to note that Csikszentmihalyi states that Flow does not happen without the application of a Skilled Performance. We suggest that implementing skilled performance conditions in gameplay design will provide the scaffold that subsequently supports Flow conditions providing an optimal experience for the player.

The heart of creating a Skilled Performance is in the development of clear goals and feedback, inducing concentration on the task at hand, both of which are the third and fourth conditions of Flow. So how does the Paradox of Control fit in? At this stage of Flow it is the feeling of control over the environment we enjoy. We gain this feeling through the development of skills. In life Flow is linked to enjoyable activities that involve risk. If we look at computer games they give us environments where we can safely undertake risky activities and in-turn they let us experience a sense of exercising control in difficult situations. Games, unlike life, are kind and reward us for our efforts. They create a sense of freedom from consequence which on the negative side can actually trap us with the addictive appeal of control and its intrinsic rewards.

If the game environment is designed well, our player will be experiencing the sense of control which allows them to relax their normal guard, releasing the sense of self from immediate threat, which delivers that loss of self-consciousness. We can then feel a union with the environment and lose our sense of self as separate from the world. It can be seen how an experience such as this can prove very appealing to a teenager who is trying to make sense of the transition from child to adult. Escape into game worlds can take away uncertainty and deliver enjoyment. The final Flow condition regards the transformation of time, but it is uncertain whether this is generated directly by the experience or is a consequence of it. Csikszentmihalyi, (1990) states that:

*It is not clear whether this dimension of flow is just an epiphenomenon - a by-product of the intense concentration required for the activity at hand-or whether it is something that contributes in its own right to the positive quality of the experience.*

At present we cannot design this element into the gameplay but we can decide to measure for it when assessing gameplay to establish if Flow is a part of the experience.

#### **3.1.4.1 The Intersection of Skilled Performance and Flow**

This section provides analysis of the elements that contribute to an effective Skilled Performance alongside the conditions that comprise an optimal experience or 'Flow' state presented by Csikszentmihalyi. The analysis focuses on establishing relationships which support the criteria of learning and game design through the application of Skilled Performance. Each of the four Skilled Performance

principles followed by the three Phases of Skill Learning were considered in turn against the eight Flow conditions and their component elements. It is worth noting that Flow conditions three and four relating to goals and feedback are combined so we are only dealing with seven separate Flow conditions. Therefore the details of each Flow condition were considered for relevance and support. The seven conditions are: 1. A Challenging Activity That Requires Skills, 2. The Merging of Action and Awareness, 3. Clear Goals and Feedback, 4. Concentration on the Task at Hand, 5. The Paradox of Control, 6. The Loss of Self-Consciousness and 7. The Transformation of Time. Table 3.2 provides an overview of where we assess Flow and skilled performance conditions to intersect. The table theorises which Flow conditions could be designed for and which would be of the user. The following two sections will attempt to argue the reasoning behind the intersecting of these two theories at these intersections.

Table 3.2 – A matrix displaying the proposed intersection of Skilled Performance conditions and Flow

Skilled Performance Conditions	Flow Conditions - the conditions for and of an optimal experience						
	For – Can be designed for				Of – experienced by the user		
	1. A Challenging Activity That Requires Skills	2. The Merging of Action and Awareness	3. Clear Goals and Feedback	4. Concentration on the Task at Hand	5. The Paradox of Control	6. The Loss of Self-Consciousness	7. The Transformation of Time
<b>Skilled Performance principles</b>							
1. Structural	●	●		●		●	
2. Goal	●		●	●		●	
3. Clarity	●		●	●	●	●	
4. Comparison	●		●	●			
<b>Phases of Skill Learning</b>							
1. Early (Cognitive)	●	●		●			
2. Intermediate (Associative)			●	●	●	●	
3. Final (Autonomous)		●		●	●		

● represents the most optimal intersections between Flow and Skilled Performance

Firstly, we will address the four principles of a skilled performance and how they relate to the seven categories of Flow as laid out in the table 3.2. We will then address the three phases of skill learning and where possible describe where flow conditions are supported. We will also make suggestions for their game design relevance where warranted. Our analysis was framed around these questions:

- *What element of Flow conditions relate to a Skilled Performance?*
- *What elements of Flow support motivation conditions in a Skilled Performance?*
- *What elements of the Flow can be utilised in game design?*

These questions were considered based on Skilled Performance as a criterion of learning. The analysis approach taken in the creation of a table, allowed us to cross reference the descriptions of a skilled

performance as outlined by Fitts & Posner, (1967) with the descriptions of the Flow conditions outlined by Csikszentmihalyi, (1990). This table can be seen in Appendix A.1. Direct quotes by Csikszentmihalyi's are '*italicised*' in the following text.

### 3.1.4.2 Flow and the Four Principles of Skilled Performance

Here seen at the header of this list is the Skilled Performance principle a directly quoted from Fitts & Posner, (1967). Below that is the gameplay interpretation of that principle taken from the authors Master's thesis work and detailed in section 2.3. Below that are the related Flow conditions relevant to the skilled performance condition as shown in Table 3.2 above.

**1. Skilled Performance principle:** A Skilled Performance always involves an organised sequence of activities.

**Gameplay interpretation:** The Structural principle – A logical gameplay structure forms the best experience for Skilled Performance

**Related Flow conditions:** 1) A Challenging Activity That Requires Skills, 2) The Merging of Action and Awareness, 4) Concentration on the Task at Hand, 6) The Loss of Self-Consciousness.

#### Reasoning:

- **A Challenging Activity That Requires Skills:** creates the structure for a Skilled Performance you need to involve sequences of activity. In the case of games we design a logical structure of skill based tasks. These form the '*sequences of activity, goal direction and rules*' which best meet the requirements for Flow.
- **The Merging of Action and Awareness:** '*does not happen without the application of Skilled Performance*'. By creating the structure for a Skilled Performance we also create the basis for this Flow condition. The structural principle is considered first when designing gameplay and due to this we should be laying a foundation for the merging of action and awareness to happen across the whole game scenario.
- **Concentration on the Task at Hand:** is achieved in our game as we need to '*exclude the interference of disorder in consciousnesses*'. This is again brought about through '*the clearly structured demands of the activity imposing order*'. So logical, sequential activity can be said to promote concentration.
- **The Loss of Self-Consciousness:** is achievable because the sense of self is not threatened. It is the structure and organisation in the activity that allows this to happen. Csikszentmihalyi says '*because enjoyable activities have clear goals, stable rules, and challenges well matched to skills,*

*there is little opportunity for the self to be threatened.* Well-designed game environments can provide the framework to achieve this, as they create safe but challenging scenarios, making it possible for the self to explore the full reaches of the experience.

**2. Skilled Performance principle:** Skilled behaviour is goal directed.

**Gameplay interpretation:** The Goal principle – Any task that requires some skill has to aid you in the attainment of your goal.

**Related Flow conditions:** 1) A Challenging Activity That Requires Skills, 3) Clear Goals and Feedback, 4) Concentration on the Task at Hand, 6) The Loss of Self-Consciousness.

**Reasoning:**

- **A Challenging Activity That Requires Skills:** is common to all the Skilled Performance principles as they create the conditions for *‘activities that are goal-directed and bounded by rules’*. In this particular instance both skilled behaviour and Flow require goal directed frameworks. So when designing gameplay scenarios the goal principle forms a sound basis from which to progress.
- **Clear Goals and Feedback:** not only do skills have to be goal directed to achieve a Flow experience they also need to be clear and combined with immediate feedback. Csikszentmihalyi’s view is that for a person to achieve Flow they must learn to set their own goals whilst recognising and gauging the feedback produced. Without this happening the person is unable to enjoy the activity. This is an area where game design provides specific support. In gameplay the requirement of goal-setting is imbedded in the structure. Designed well, the goals should be clear, generating the strong possibility that the experience will facilitate a intrinsically rewarding Skilled Performance.
- **Concentration on the Task at Hand:** To enable concentration of the level needed to reach a Flow state we again require *‘clear goals and immediate feedback’*. This in turn provides the order to consciousnesses we need to fully concentrate on the activity and its outcomes, allowing skilled behaviour to develop.
- **The Loss of Self-Consciousness:** as with the first Skilled Performance principle, is delivered through the organisation and structure of the tasks undertaken to acquire the skill. To meet Flow requirements these *‘enjoyable activities have clear goals, stable rules, and challenges well matched to skills’*. Loss of self-consciousness can lead to a growth of the self which develops through the goal directed activity, whilst the player’s skills are constantly being perfected.

**3. Skilled Performance principle:** The full complexity of sequential activity can seldom be understood except when the end objective or goal is also understood.

**Gameplay interpretation:** The Clarity principle – Make the goal clear to your player from the start of the task, so they can understand why they are undertaking it.

**Related ‘Flow’ conditions:** 1) A Challenging Activity That Requires Skills, 3) Clear Goals and Feedback, 4) Concentration on the Task at Hand, 5) The Paradox of Control, 6) The Loss of Self-Consciousness.

#### Reasoning:

This element of a Skilled Performance is about understanding the task at hand. It’s about having a clear picture of the activity’s relationship to the end goal.

- **A Challenging Activity That Requires Skills:** As we have already learned Flow experiences *‘occur within sequences of activities that are goal-directed and bounded by rules’*. The challenges of the Flow experience come from the sequential design of the tasks, and how the developing skills relate to the end goal. The learning and development of the subject comes from understanding the relationships between action and goal attainment, a crucial part of the learning process and key to developing the skills to meet the challenge.
- **Clear Goals and Feedback:** Skilled Performance criteria and Flow experience meet in the need for clear goals. It is the clarity of the goal that makes the difference though. Making sure you understand what you’re doing and why, is crucial to enjoyment and reward. Key to the creation of that understanding between activity and goal comes in the form of feedback. Csikszentmihalyi says *‘Feedback can be enjoyable, provided it is logically related to a goal in which one has invested psychic energy’*.
- **Concentration on the Task at Hand:** Enjoyable activities such as goal related skills and tasks *‘require a complete focusing of attention on the task at hand-thus leaving no room in the mind for irrelevant information’*. This can be made possible in game design by making the skill related task clearly support the activities goal, letting the *‘clearly structured demands of the activity impose order, and exclude the interference of disorder in consciousness’*.
- **The Paradox of Control:** *‘the Flow experience is typically described as involving a sense of control’*. Sense of control is worth mentioning here because only through the understanding of a situation can we feel a sense of control over it. The player of a game may have no control over its design but through understanding what is required of them in that environment *‘the possibility, rather than the actuality, of control’* is created.

- **The Loss of Self-Consciousness:** is again afforded here to the structure and sequencing of the activity. By following the Skilled Performance principle in game design we can encourage the 'self' of the player letting them feel safe to explore and grow.

**4. Skilled Performance principle:** Each act is dependent upon comparison of what [the player] thinks is desired, either through feedback (external stimuli) or comparison of progress towards a goal.

**Gameplay interpretation:** The comparison principle - The player needs a response to their actions to be able to compare how well they are doing in relation to their desired outcome or alternatively the player needs to know how their actions have progressed them in attainment of their goal.

**Related 'Flow' conditions:** 1) A Challenging Activity That Requires Skills, 3) Clear Goals and Feedback, 4) Concentration on the Task at Hand.

#### Reasoning:

The main focus for this Skilled Performance principle is the direction it gives regarding feedback.

Requirements for both Skilled Performance and optimal experience require feedback for effective learning to take place. A game environment also utilises feedback as a core component delivered by means such as score tables, health bars or sound effects.

- **A Challenging Activity That Requires Skills:** This condition of Flow outlines the requirements which create the structure of a Skilled Performance. It is the goal direction and application of rules activity that defines the placement of the feedback points.
- **Clear Goals and Feedback:** The Flow experience requirement is also key to the achievement of a Skilled Performance and forms an integral function of successful gameplay. The role of goals and feedback allow the player to compare their learning progress against game goals and through the timely interaction of feedback. On the nature of feedback both Skilled Performance theory and Flow theory agree that *'the kind of feedback we work toward is in and of itself often unimportant. What makes this information valuable is the symbolic message it contains: that I have succeeded in my goal.'* The knowledge that feedback brings generates the desired order to consciousness which *'strengthens the structure of the self'*.
- **Concentration on the Task at Hand:** Results from the delivery of clear goals and feedback which is then experienced in the subject as enjoyment. *'The concentration of the flow experience-together with clear goals and immediate feedback-provides order to consciousness'*.

From this analysis the four principles of a Skilled Performance are primarily supported by four out of the seven of the conditions that contribute to Flow. These are, in order of most related 1) A Challenging Activity That Requires Skills, and 4) Concentration on the Task at Hand. Relevant in three instances are 3) Clear Goals and Feedback, and 6) The Loss of Self-Consciousness. Also relevant, but to a much lesser extent are 2) The Merging of Action and Awareness and 5) The Paradox of Control where. None of the principles could be directly aligned with 7) The Transformation of Time.

### 3.1.4.3 Flow and the Three Phases of Skill Learning

To achieve a Skilled Performance the learner passes through the three Phases of Skill Learning. Phase one is the 'Early or Cognitive' phase, second is the 'Intermediate or Associative' phase, before completion in the 'Final or Autonomous' phase. Here we suggest how the phases are linked to the Flow experience, while making suggestions on how they can be adopted directly into game design. The SPD model (see section 2.2.2) describes how skills build up over time in the support of a Skilled Performance. The progression through the 'Three Phases of Skill Learning' are similar to the levels of difficulty you encounter in a gameplay. These levels of difficulty do not have to occur in a linear fashion but can be delivered cyclically, one within the other until the ultimate goal of the game is completed.

### 3.1.4.4 Early or Cognitive Phase

In this first phase a learner tries to understand the task and what is being demanded of them. Fitts & Posner, (1967) state that '... a good instructor calls attention to the perceptual cues, response characteristics and gives diagnostic knowledge of results'. In this early stage behaviour can be shaped by affirming sequences of acts that resemble the correct one via positive feedback.

#### Game Design:

- game environment acts as instructor
  - Through tutorial levels, mission based learning or on-screen instructions.
  - The player utilises these elements until task completion

#### Flow context:

In this phase sympathetic design can begin to create the conditions for optimal experience as it sets up opportunities for Flow in the form of **challenging activities** which are goal directed and bounded by rules. Flow theory suggests that *'for those who don't have the right skills, the activity is not challenging; it is simply meaningless'*. So it is essential at this very early stage to develop, nurture and then build on the basic skill sets required for completion of the end goal (if we want to avoid the activity proving meaningless). Effectively designed gameplay delivers clear goals and feedback leading to **concentration**



**on the task at hand** which is an enjoyable consequence of Flow. With this as a starting point the two subsequent skill phases should also generate the remaining conditions for a Flow experience.

#### 3.1.4.5 Intermediate or Associative phase

New skill patterns are built from the cognitive phase. This results in a reduction in large mistakes, as the learner is able to merge the previously learnt skills into component sets. Fitts & Posner, (1967) advise against frequent repetition of the same skills over a short time period. They found this results in decreased performance, ascribed to decreased motivation. Likely due to the lack of increasing challenge and goal progression perceived in repetition. They do state that frequent rest periods will facilitate performance, especially in motor skills.

#### Game Design:

- Control over skills is strongly developed during this phase.
  - If the task is complex, the best method for undertaking it is to practise its separate components before attempting it as a whole again.
  - Skills are learnt faster if their components can be undertaken separately but associated together. However, it is better to learn as a whole task than break the associational context.
  - Players can also be allowed to rest between skill-set building by providing a variety of easy mini-tasks for simple rewards that can prove useful later. There is also the option to rest though opting out of gameplay activates altogether such as spending time assessing your end goal progression though other forms of information such as score statistics, character development possibilities and networked interaction with other players. It is then the players' choice if they wish to rest or continue. As all people learn at differing rates options for active and passive rest opportunities should be available in gameplay when needed.

#### Flow Context:

This phase builds on the Flow components of the previous phase in building the complexity of the **challenging activities**, which focus player attention onto their progression on the level **goals**. Here **feedback**, such as the score statistics, on goal progression is important to provide continued motivation in achieving the associative task based skills. The strategies for goal attainment and feedback on task completion in this phase should feed the ability to **concentrate on the task at hand** and as errors are reduced as the skills are achieved we should be generating sense of **control** or mastery over the environment. This should be sufficient to fuel the **loss of self-consciousness** which contributes to the

growth of the self through the constant perfection of skills. *‘This growth of the self occurs only if the interaction is an enjoyable one, that is, if it offers nontrivial opportunities for action and requires a constant perfection of skills’* (Csikszentmihalyi, 1990, p65)

#### 3.1.4.6 Final or Autonomous phase

Here the skills learnt become increasingly automatic. The learner thinks less about what they are doing and outside stimulus has less affect. Old skills and new are developed side by side as the old skills require less processing. It is the predictability of the old skill which supports the new skill and allows it to develop.

#### Game Design:

- The player needs less direction so new more challenging skills and environments can be introduced.
- In this phase the player would expect to encounter the level goal or final game goal. For example this can take the form of a ‘Boss fight<sup>5</sup>’ where all the learnt skills are combined to defeat the enemy, solve the puzzle or achieve the highest score.

#### Flow Context:

This phase of skill learning encapsulates the Flow experience. It is in this phase when all the learning tasks combine to create the skilled performance. The **merging of action and awareness** is an apt description of this phase, as the person's attention is absorbed in the activity. They are applying all their relevant skills to cope with the challenges. As Csikszentmihalyi, (1990) p53, states *‘people become so involved in what they are doing that the activity becomes spontaneous, almost automatic; they stop being aware of themselves as separate from the actions they are performing’*. This phase's impact on Flow should be seen through the **paradox of control** as it allows *‘the practitioner to develop sufficient skills to reduce the margin of error’* leading to the **loss of self-consciousness** that comes with *‘challenges well matched to skills’*. Achieving the autonomous level of skill learning, where all the learnt skills flow together, provides an autotelic optimal experience that is Flow in action. This level of experience is where the activity becomes intrinsically rewarding. This peak performance will inevitably return to the fight between boredom and anxiety as a set of new, more challenging activities undertaken.

### 3.1.5 Summary

Use of the Skill Performance principles in conjunction with the Phases of Skill Learning should create a framework for an enjoyable, effective learning experience. Applying the framework of the ‘Structural

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<sup>5</sup> A Boss fight is a gaming term for a final high-level challenge activity

Playability' model in the design of gameplay should promote Flow and learning, as Flow is so closely linked to what constitutes a Skilled Performance.

A key factor that contributes to learning, comprehension and knowledge is feedback (Aguilera & Méndiz, 2003; Cowley et al., 2006; Csikszentmihalyi, 1990; de Freitas & Oliver, 2006; Garriss et al., 2002; Wei & Li, 2010). Feedback is important to develop knowledge for the development of a skilled performance and Flow. With goal related feedback of prominence in both Skilled Performance and Flow. Gameplay that provides clear goals and relatable feedback as suggested in this section outlines a different approach to 'drill and skill' teaching practises where the end goal might not be so apparent and feedback less tangible.

### **3.2 Exploring the Structural Playability Approach**

Our analysis of motivation and Flow theories, in the context of game design, provided new information, enabling us to enhance and support the skilled performance based SPD model discussed in section 3.1.2. The exploration of these theories enabled us to propose connections between Skilled Performance principles and Flow conditions, thus strengthening our proposition that Skilled Performance provides a sound scaffold for engaging gameplay. Flow, in comparison to Fitts & Posner's (1967) Skilled performance theory, has been widely accepted by academic theorists in relation to game design. These theorists have developed assessment measures for Flow that can we can bring to the assessment of Skilled Performance based game outcomes The value of Flow, from a design perspective, is in its ability to describe the optimal experience through a set of relatively simple and universal conditions. The understanding of Flow conditions provides a contextual boundary describing the perceived experience of our designed skilled performance approach. The contextual boundary of Flow tells us we are designing our gameplay to be balanced between boredom and anxiety, as this will motivate our player to build their skills. As Csikszentmihalyi, (1990) say's Flow *'Does not happen without the application of skilled performance'*.

However, before we can undertake a skilled performance or experience Flow we must first address motivation. Our investigation into motivation theories led us to conclude that the Structural Playability Design (SPD) model lacked the essential educational context for effective design.

The SPD models strengths are in providing the theoretical detail for the translation of a game concept into gameplay content. Its limitations however are found in its scope. The SPD focuses on post narrative gameplay mapping and doesn't have a provision for pre-narrative mapping or the later structuring of gameplay mission for game-engine implementation.

The SPD model assumes the designer has already been given a narrative context upon which to develop the gameplay. However, the literature review highlighted that academic models tend to lack a clear, practical process that a designer can follow for gameplay development (Amory, 2006; Cowley et al., 2006; Finneran & Zhang, 2003; Garriss et al., 2002; Kiili, 2005). Therefore, if the intention is to use the SPD model as an approach for the practical design of educational games, it requires expanding. Not only in terms of a clearly defined educational narrative, but to also include the method by which the narrative can be implemented into the game engine. These limitations led us to revisit the SPD in a broader form, as a more practical design process for learning gameplay.

The new approach was named as the Structural Playability Process (SPP). The advantage of this new approach is how it allows the designer to breakdown the gameplay process into a set of spaces that can be understood by all stakeholders in the development process, from the client with the game idea to the engine programmer. It shifts the focus from the detailed presentation of Skilled Performance theory shown in the SPD model to concepting the design through a set of spaces that address the process of the gameplay design.

Each of space of the SPP is explored in more detail in sections 3.2.1 to 3.2.4. The different development spaces are:

- 1) Educational space; where the learning problem is assessed against player motivation and translated into learning outcomes.
- 2) Translation Space; where a simple narrative is constructed.
- 3) Design Space; where the learning outcomes are redefined as gameplay goals
- 4) Engine Space; where the gameplay missions are formed to deliver the learning content.

Figure 3.3 illustrates the full mapping process of the Structural Playability Process (SPP). To provide context the left-hand side lists the new 'Spaces' criteria, while the right-hand side shows the relationship of the SPD model stages. You will note that the core of the SPD model operates between the Translation space and the Design space. The additions in the SPP approach are mainly present in the Educational and Engine Spaces. The Engine space provides more detail to the mapping of gameplay missions that would be required in game production.

It is important to understand that these different spaces provide a guide, in the form of a simplified approach to exploring educational game design. These spaces will overlay each other with parity

between Complex problem, Narrative, Skill Stages and Metrics and between Learning Outcome, Primary Game Goal and Gameplay Missions. As the nature of design is iterative, we are attempting to describe a cyclic process that has many complex interactions in a simplified linear format. We hope that this simplified format will be useful for guiding those wishing to be involved with educational game design and development, from both a client and designer perspective.

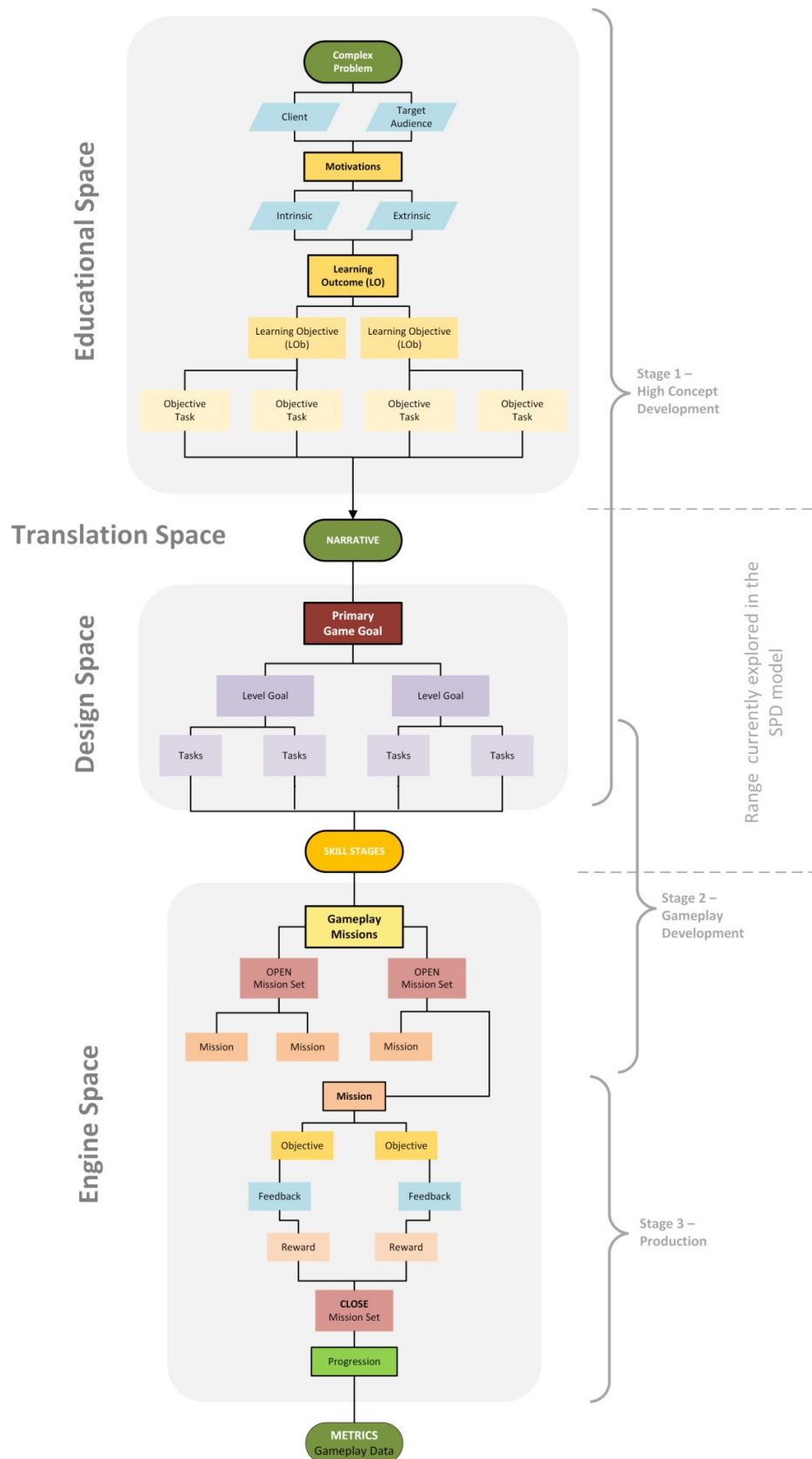


Figure 3.3 - Structural Playability Process (SPP) – Mapping educational gameplay

### 3.2.1 Educational Space

The exploration into motivation theories (Deci & Ryan, 1985; Maslow, 1999) provided a framework from which to develop the educational narrative. This is a user centred approach that addresses the motivations of the target audience leading to the definition of clear learning outcomes. The focus of this stage is for the designer to engage with the client. The client brings the complex problem they wish to explore through gameplay. It is the role of the designer at this stage to enable the client to define that problem from an educational gameplay viewpoint. This is the exploratory stage in developing effective gameplay (Fig. 3.4).

- *Step 1 - Identifying the problem*

An educational game requires an educational purpose that can be developed into learning outcomes. Firstly you need to define the problem.

- *Step 2 – Purpose*

From a design standpoint there are two sets of motivations that need to be addressed in the gameplay; those of the client and those of the target audience (TA).

- The client defines the purpose of the game and will have expectations for the game outcomes, such as a maths game teaching algebra.
- The TA may not have the same expectations as the client. They may just be curious about the topic but have no specific goals in mind. This is where the definition of motivations become key to the development of the learning outcomes and subsequent gameplay.

- *Step 3 - Motivations*

To engage your TA with the educational game it is key that you define their motivations with respect to the problem or topic that you wish to turn into the gameplay experience. The designer should be asking the client, are your goals and motivations the same as your TA? If not what common ground can be found? How can you translate the TA's motivations into an approach for achieving a learning outcome that meets the needs of the client?

- Deci & Ryan, (1985) described motivations in terms of intrinsic and extrinsic. Both the client and the TA need to have their motivations explored. The Intrinsic motivations are

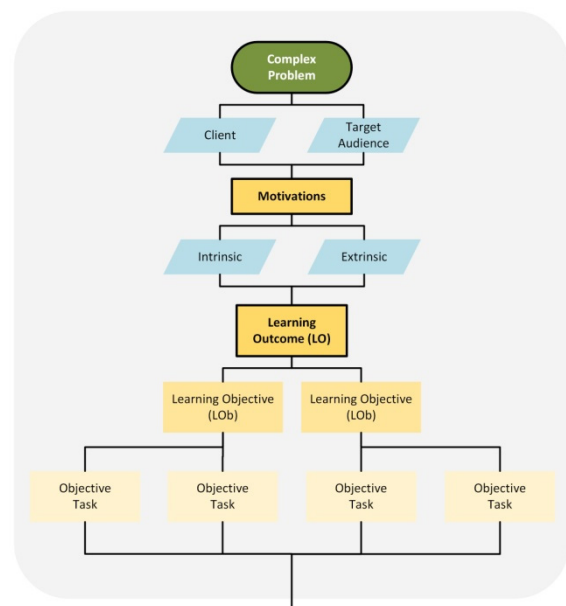


Figure 3.4 - Educational mapping section

those that will form the basis of the gameplay and provide the basis for engagement with the topic. They are motivations that are internal to both client and TA. If they can be shared by both it will provide a stronger premise for the gameplay design. For example, from the perspective of a maths game both the client and TA intrinsic motivations could be described as wanting to teach more about maths to the TA who wants to learn more about maths. These intrinsic motivations cross over and form a shared point for engaging with the design outcomes.

- Extrinsic motivators are items that can be used to drive the learning and gameplay forward. In terms of our maths example they might be that the TA wants to learn about maths as they wish to pass an exam on algebra.
- The TAs motivating factors in regard to your topic/problem whether positive or negative will form the basis of the narrative from which the gameplay will hang. The TAs motivators will be used to embed the learning outcome/s so that the overtly educational message is attached through a narrative based upon the TAs intrinsic and extrinsic motivators.

- *Step 4 - Forming the learning outcomes*

Using learning outcomes for the defining and assessing of student performance is well established in higher educational practise. This practise is used in university courses to define the taught topic in terms of outcomes that a student can expect to achieve on completion of the course. In her review of learning outcomes in higher education, Allan, (1996) concluded:

*Learning outcomes have evolved both from rational curriculum design and the work of Eisner. Consistent with the work of Tyler (1949), Mager (1962), MacDonald-Ross (1973) and Eisner (1979), the use of outcomes emphasises student achievement and affirms that curriculum planning should begin with what is learnt rather than what is taught.*

Learning outcomes ‘articulate the relationship between what [educators] teach and what students do, in fact, learn’. Bringing this well-developed academic process of defined learning around outcomes provides a method for transferring knowledge into gameplay practises

The learning outcomes should be based on the intrinsic motivations and supported by the extrinsic motivations. Which brings us back to thinking in terms of the governing skilled performance principle which is that ‘Skilled behaviour is goal directed’ and returns us to the Goal principle: Any task that requires some skill has to aid you in the attainment of your goal, because ‘Skilled



behaviour is goal directed’. The learning outcome should be developed so it is goal directed. The higher level learning outcomes can be further explored by breaking down the outcomes into sets of learning objectives. These can be further broken-down into sets of tasks. This provides a strategy for the initial complex problem to be translated into a set of manageable steps for both the TA and the design team.

- *Step 5 – Learning Objectives*

With the basis of the learning established through the learning outcome and objectives. You can redefine the purely educational outcome in terms of gameplay goals before moving on to deal with the narrative.

### **3.2.2 Translation Space**

The translation space is where the designer and client collaborate to embed the learning, integrating it so that the learning outcomes are not overtly experienced during the gameplay. The Learning Outcome should underpin and not dictate the TAs experience. To emulate the engaging aspects of entertainment based gaming, the designer should focus on translating LOs through the application of narrative to achieve a set of game goals that build the contextual situation.

Narrative has been extensively used by human beings as a means for expressing information, both fiction and non-fiction, for thousands of years. Narrative starts with the very history of mankind; there is not, there has never been anywhere, any people without narrative (Barthes & Duisit, 1975). Narrative displays the goals and intentions of human actors; it makes individuals, cultures, societies, and historical epochs comprehensible as wholes; it humanises time; and allows us to contemplate the effects of our actions, and to alter the direction of our lives (Richardson, 1990). Narrative is also valued as a vehicle of morality with Vitz, (1990) asserting that ‘narratives (stories) are a central factor in a person's moral development’. Narrative has the ability to induce empathy between audience and content through devises such as establishing ‘point of view’ early on leading to the narrative content being remembered with more accuracy (Coplan, 2004).

Employing the power of narrative structure provides us with a sound approach for the translation of educational content. Our purpose is to support the self-determinism of the TA, through correctly mapped motivations, within a narrative that creates the opportunity for immersion and ideally empathy with the learning outcomes, objectives and tasks of the initial complex problem.

To establish narrative we can begin to think in terms of our motivations and how they lead to the gameplay goals. Gameplay goals take three forms and these goals should reflect as strongly as possible the client and TAs motivations. The goals act to drive the gameplay progression. These three forms are:

- Aspirational/long-term Goals (intrinsic)
- Mid-range goals (intrinsic/extrinsic)
- Short-term immediate goals (extrinsic)

These variations in goals reflect the phases of skill learning.

Aspirational goals by their nature are more complex and difficult to achieve. Short-term goals are in comparison easy to achieve

and mastery of these can lead to acquisition of more complex mid-range goals. The narrative that is drawn up to support the motivational goals provides the player with a starting point into the gameplay. The gameplay design should support narrative discovery, by housing the learning outcome and objectives in a logical framework, engaging the player with the learning content (see Fig 3.5 for the positioning of narrative in the SPP structure).

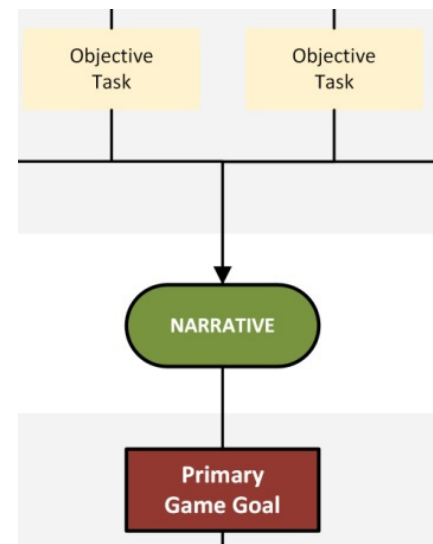


Figure 3.5 – Narrative mapping section

### 3.2.3 Design Space

This space is where the learning content having been filtered through a narrative is now mapped into gameplay. This section provides us with a simplified outline of the process for governing gameplay levels presented in the section B and C of the SPD model. We propose that this view is simpler to comprehend from the client perspective when working with the designer to define the goals and tasks (see Fig 3.6).

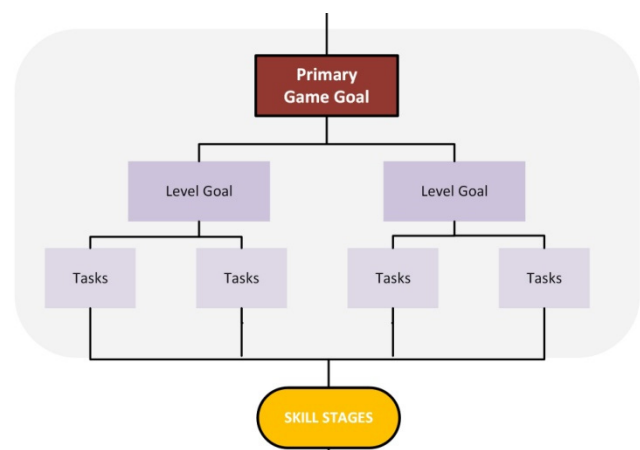


Figure 3.6 – Simplified gameplay mapping

These design steps are the gameplay equivalent of the steps from the educational space but they are in keeping with the proposed narrative:

- Step 1 – re-form the learning outcomes as the primary game goals.
- Step 2 – re-form the learning objectives as level goals that support the narrative structure.
- Step 3 – the objective tasks become gameplay tasks seen through the narrative lens.
- Step 4 – filter through the tasks into skill stages as outlined in the SPD model

This is the point where the design is drawing upon the Phases of Skill Learning and interpreting the learning content as gameplay goals that flow within a level based structure. This is a starting point and we are unsure if direct mapping is possible but this goes some way to providing a structural system and approach that clearly links learning outcomes and the gameplay equivalents.

### 3.2.4 Engine Space

In the limitations of the original SPD model was that it stopped before dealing with gameplay development. And the strategy for applying the skill stages for application in a game engine was only lightly touched upon. Here we present a method that takes our learning outcomes and their objectives that we have already interpreted into skill stages in the design space and apply them in terms of gameplay missions (Fig 3.7). Again this is at present a theoretical method for developing the gameplay and it needs to be tested though building a game engine through code.

What we propose here is that the skilled stages that have been mapped for each level are directly recoded in terms of mission structures. These are the goal directed logical structure of the skilled

performance principle of 1) Structural and 2) Goal. The idea is that before we reach this point we have implemented the motivations and principle of a skilled performance in the design and now we are dealing with the implementation structure. The intention is that a designer and programmer can work together to implement this structure in the game engine. By keeping this logical structure we hope to ensure that the integration of the learning outcome and objects stays embedded throughout the gameplay experience. In this way we create support for skilled tasks that proved clear goals, appropriate feedback and motivating rewards.

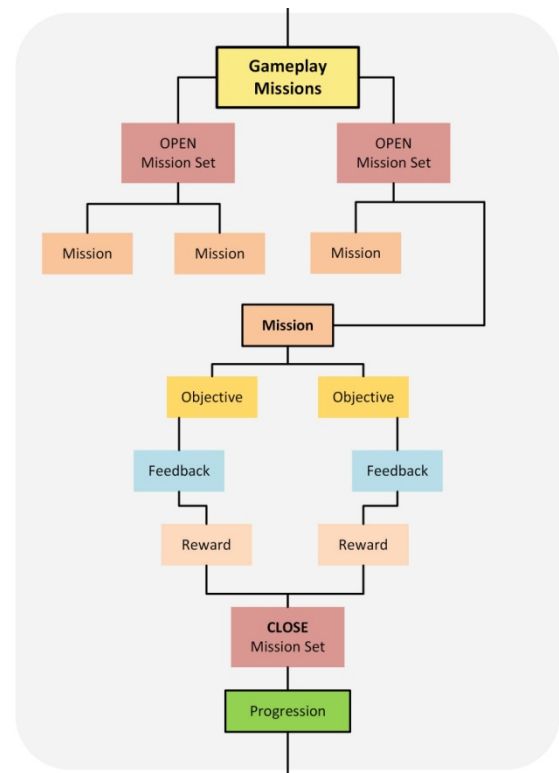


Figure 3.7 - Mission mapping for game engine implementation

### 3.3 Research Strategy

The theoretical approaches outlined in the Structural Playability Design (SPD) and Process (SPP) models are the responses formed in the attempt at answering our research question. '*What is an effective design process for computer games that deliver structured learning activities?*'

In order to answer the research question a Hypothesis was formed:

*H<sub>1</sub>: The Structural Playability Process of educational game design acts as an effective design approach for delivering structured learning activities.*

To answer this question and test the hypothesis as fully as possible we explored the process through the design and development of two different computer games;

1. **GeoThermal World** - a free roaming 3D exploration game for student geologists to explore geothermal recourses, and
2. **Ora – Save the Forest!** - a simulation driven game for pest management in New Zealand forests.

Both games were commissioned by external clients who had never previously been involved in a game design or development project. The design and build of the games followed the strategy outlined in both the SPD model and the subsequent SPP approach.

The Unity3D<sup>6</sup> game Engine was chosen for the development of both games. Unity3D combines relatively low-cost licensing; approximately NZ\$1500 for educational use, with cross platform flexibility (PC, Mac, mobile), and a high level of user support (manuals, user forums and asset store).

We chose the Unity3D game engine for the game build as it provide flexibility across 2D and 3D projects. It is well supported with additional assets and plug-ins via the online Asset Store and has an active forum community for help and advice. The engine is aimed at independent developers and offers reduced price academic licenses making it suitable for the needs of both projects.

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<sup>6</sup> <https://unity3d.com/>

### 3.3.1 Development Questions

To answer the research question and explore the hypothesis, the research was loosely structured into two streams, **Stream a)** factors that focused on the design process and **Stream b)** factors that focused on structured learning activities. The following set of questions were formed to structure the investigation:

1. Can the SPP be followed as a design approach when used with a real-world client problem?
2. Can the designer implement the learning outcomes and objectives of the client into a gameplay system that can be built in a game engine?
3. Will the games meet the learning outcomes of the client through providing the Target Audience with an engaging gameplay experience that provides subject knowledge?

Question 1 and 2 fell under stream a) and question 3 under stream b). We address development questions 1 and 2 through reporting on the design implementation of each game. We then address question 3 through undertaking and reporting on a user study that tested each game.

### 3.3.2 Project Roles

The author undertook a number of roles in this research which figure 3.8 outlines, including Research Investigator, Designer, and Developer.

The role which governs the doctoral research work is (1) Research Investigator. In this role the author observes and records what is happening as a result of following the SPP game design process, and is responsible for the user study and experimental design required for testing the game design outcomes.

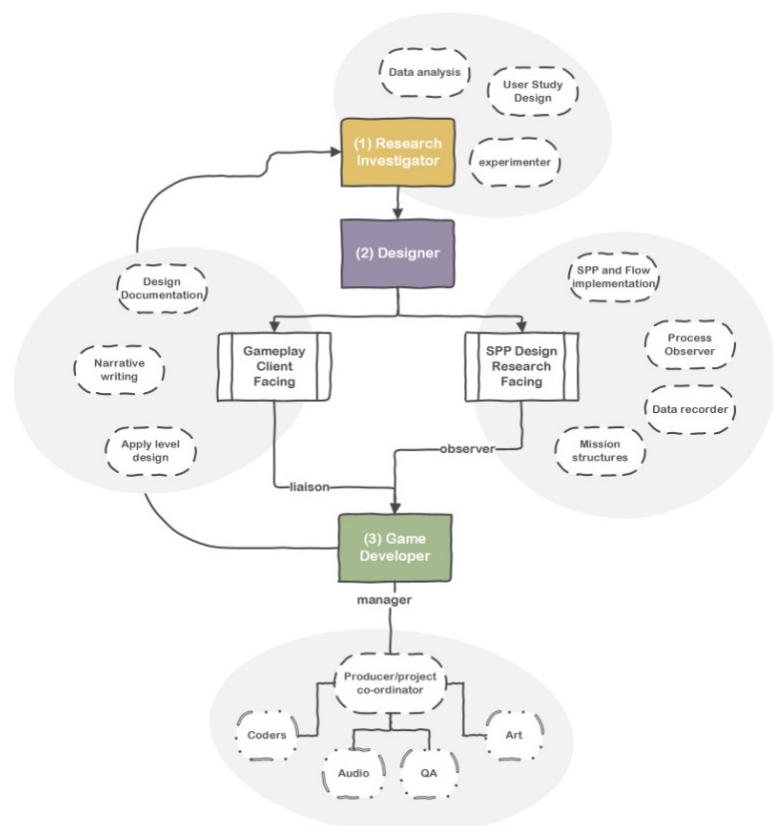


Figure 3.8 -Mapping the authors roles in the research

The role of (2) Designer is where the main body of the practical investigation of the research takes place. This role has two forms, one being the client facing gameplay role in pursuit of developing a game that has practical value for the clients

aims. This role draws upon standard games industry procedures for capturing and recording design decisions. The second role is as a designer exploring the SPP approach. In this role the designer attempts to follow the process laid out in the two models, SPD and SPP. This is a process of discovery and adaptation with regard to the practical application of the SPP in a real-world, client driven project.

The author's final role comes in the form of (3) Game Developer. This is the role that requires the application of project management skills where the author acts as a production manager co-ordinating the game build, managing the team and allocating resources. This role does not directly inform the active research, but allows the author as designer to understand the limitations and practicalities that production process can have on a design strategy.

### **3.3.3 Development and Experimental Strategy**

The design strategy took the client through the Educational Space, leading to the establishment of a workable narrative from which to begin the design. The Design space is heavily directed by the SPD model parameters, where the design follows the Skilled Performance gameplay principles. The SPP's Design Space simplified 'client friendly' structuring of the developing game concept. Outputs from client/designer interaction in this space result in shared design documentation between client, designer and production team. This conceptual documentation provides the structure of the gameplay content, and look and feel of the proposed game.

With these conceptual conditions agreed the designer is able to begin the aspects of production prototyping such as User Interface (UI) design, in-game features such as tools, and setting up the world environment in the game engine. Exploring features such as character control, camera position and environment look and feel. At this point the prototyping of assets and interactions can be developed separately from the mission system.

Not only do we want to assess the design process for ease of use by the designer and client, we also must assess the impact of the games in meeting their intended purpose as learning objects. Finally, we address our research question through an experimental design approach.

Figure 3.9 illustrates the test strategy employed to measure the outcomes of the TA gameplay interaction. We measured participant responses to the game experience in two ways:

1. To assess whether the gameplay goals, and therefore the learning objective and outcomes, had been met we assessed knowledge acquisition levels before and after play.
2. To establish the value of the SPP process, and its scaffold use of Skilled Performance, we measured participant perceptions of Flow conditions after play to infer the level of 'goodness'.

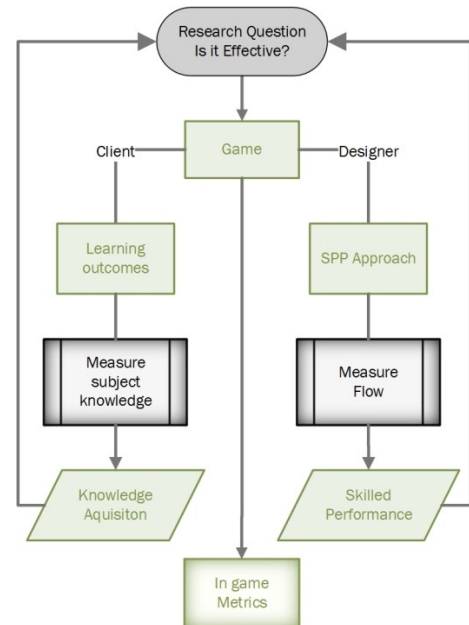


Figure 3.9 - Experimental test strategy

To add a note of clarification, the user-studies do not directly measure the SPP itself, but rather they collect data on the gameplay experience that is empirically measurable. From this data it is possible to draw inferences on whether the SPP design has caused the gameplay to have certain properties.

To investigate the effectiveness of the gameplay an exploratory baseline approach was used. In the user-studies we compared a baseline of a traditional tutor-led teaching approach, to our game-led self-directed approach. Both approaches shared learning outcomes and objectives. Knowledge acquisition and Flow scores were collected for both situations with the results were used to assess the impact of the game design.

### 3.3.3.1 Knowledge Acquisition

To ensure the suitability of the knowledge assessment methods we were guided by the Bloom's Taxonomy of learning goals. 'The original Taxonomy provided carefully developed definitions for each of the six major categories in the cognitive domain. The categories were Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation (Krathwohl, 2002).

In educational terms the two gameplay sessions would be relatively short learning experiences. The participant would take part in only one session lasting no more than two hours. Considering these limitations it was anticipated that the experience would primarily support for learning at the level described in the first two categories of the taxonomy; (1) Knowledge and (2) Comprehension. Knowledge describes the recall of data or information such as fact recollection. Whereas,

Comprehension displays a slightly deeper understanding with a learner being able to state a problem in their own words. Therefore, three styles of question were chosen to measure knowledge acquisition levels anticipated from participation in the study. These were a set of multiple choice questions (MCQs), a visual/spatial style question, and a short answer, open ended question.

The MCQs consists of a written question and a list of possible answers. The use of MCQs provided a reliable measure that was simple to administer and directly targeted topic knowledge. They fall with the Bloom's Knowledge category measuring simple data recall. The visual/spatial question provided an image linked to the gameplay setting followed by questions on the data contained in the image. This question required the participant to interpret the data in the image before answering the related questions. This is on step up from the written MCQs as it required deeper thinking in interpretation of the image.

The open-ended short answer questions measures domain knowledge and the reasoning behind the knowledge. The question is framed via a contextual introduction directly linked to the learning objectives of the gameplay. The participant is asked to list observations they'd expect to make in the gameplay's setting before being asked to provide the reasoning behind their observations. They may supply as little or as much information as they sit fit. This question is within the Comprehension category of Bloom's taxonomy as more critical thinking is being called upon. Short answer questions 'are commonly used in examinations to assess the basic knowledge and understanding (low cognitive levels) of a topic' (Chan, 2009).

### **3.3.3.2 Skilled Performance via Flow**

Flow theory is normally assessed over a long period of time through the use of the Experience-Sampling Method (ESM) of measurement (Csikszentmihalyi, 1990). In this case we needed a valid method of measuring for the conditions of Flow that suited a short term study and that was pertinent to both learning environments.

The questionnaire used in this research was an adaptation of the EGameFlow measure (Fu et al., 2009) which, in turn, was developed from Sweetser and Wyeth (2005) *GameFlow: A model for Evaluating Player Enjoyment in Games*. Sweetser and Wyeth describe their model as having 'drawn together the various heuristics [in gaming literature] into a concise model of enjoyment in games that are structured by Flow.' They go on to describe that their 'new model, GameFlow, consists of eight elements – concentration, challenge, skills, control, clear goals, feedback, immersion, and social interaction'.



Fu et al. takes these elements and uses them as the basis of a scale of measurement for enjoyment in an e-learning game setting. They validate the EGameFlow scale by testing against player enjoyment on four different e-learning games. Fu's scale consists of eight dimensions: Immersion, social interaction, challenge, goal clarity, feedback, concentration, control, and knowledge improvement. They tested a range of statements for each category that could be used in a Likert scale questionnaire. For this study we adapted the EGameFlow scale by selecting three of their validated questions from each of the eight categories most relevant to our studies. Alongside the EGameFlow categories we added our own category of Enjoyment. This additional category would act as a simple indicator of our participants' overall experience, providing a baseline against which to consider the level of perceived Flow.

Fu et al. report that the EGameFlow scale has good internal consistency, with a Cronbach's alpha coefficient reported of .942 for the 42 items as a group and >0.8 for each separate dimension. Their findings show that the validity and reliability of the scale, EGameFlow, were satisfactory. Thus, EGameFlow is an effective tool for evaluating the level of enjoyment provided by e-learning games to their users (Fu et al., 2009). A Cronbach's alpha coefficient was conducted for the adapted EGameFlow scale used in our research studies and have a coefficient of .872 for the GeoThermal World study and .925 for the *Ora – Save the Forest!* Study (see sections 5.6.2 and 7.6.2 for further detail). The complete list of the questions used in the adapted EGameFlow questionnaire is available in Appendix A.2.

### **3.4 Summary**

In the previous chapter we introduced the Structural Playability Design (SPD) model, which applies Skilled Performance theory (Fitts & Posner, 1967) as a gameplay framework. We theorised how the motivational concepts of self-determination and self-actualisation (Deci & Ryan, 1985; Maslow, 1999) can influence game design strategies. Along with the presentation of a detailed exploration how Skilled Performance principles can be used as a scaffold for the conditions of a Flow state (Csikszentmihalyi, 1990). We also presented the Structural Playability Process (SPP) approach of educational game design that is informed by motivation and Flow theories and builds upon the SPD model framework. Finally, I also gave an overview of the research strategy for the development of two game projects that will allow the testing of effectiveness of the SPP as practical game design approach

### **3.5 Introduction to the Chapters**

The remainder of this thesis will be dedicated to the design, development, testing and interpretation of the two commissioned games. The design implementation of each game (Chapters 4 and 6) will be presented before details of each user study (Chapters 5 and 7). The user studies will present the experimental design and findings. The final chapters (Chapters 8 and 9) will discuss the findings from both games in an attempt to support the hypothesis and answer the research question - ***'What is an effective design process for computer games that deliver structured learning activities?'***.

# 4

## GeoThermal World: Design Implementation

This chapter outlines the steps taken in the design implementation of the GeoThermal World game. It attempts to illustrate the process that was undertaken by the designer in order to address the development questions, as laid out in the research strategy section of chapter 3.

These questions are:

1. Can the SPP be followed as a design approach when presented with a real-world client problem?
2. Can the designer implement the learning outcome and objectives of the client into a gameplay system that can be built in a game engine?

We present the design process of the game via the simplified linear form of the SPP approach, with reference to the earlier SPD model where appropriate. We will address each design space in turn, beginning with an overview of the full game via the Educational and Translation spaces, before providing specific details of the level, gameplay and mission designs in the Design and Engine spaces.

*GeoThermal World* is a serious game designed to enable student geologists to learn about the field of Geo Thermal energy in a safe, realistic and engaging environment. The 3D game world teaches students about geothermal field exploration through the use of realistic tools and measures. It embeds learning outcomes into game-world missions by supporting the player through an integrated system of progression points, rewards and contextual feedback. In addition, the world is designed to allow the player to balance the challenge of working in an ecological and environmental manner within the economic realities of a large corporation.

Players explore a visually accurate representation of the Mount Edgecumbe/ Putauaki volcanic area in North Island, NZ. Dynamic 3D digital modelling creates a virtual reality terrain from mapping data, and allows 'free roaming' by players, reflective of current large-scale entertainment based gaming. Intricate details of hot-pools are re-created, showing flowing water, vent activity and steam clouds (see Fig.4.1).



Figure 4.1 – View over the Sapphire Pools of GeoThermal World

During the game student geologists are immersed in the virtual world, allowing them to experience the complexities of geothermal geology and exploration through safe, realistic, and engaging gameplay. Players complete a variety of ‘real-world’ missions, while collecting and assessing data, taking photographs and recording field notes.

In the previous chapter (section 3.2) we outline the SPP design process, and its structure for game development, which comprises the following four related spaces:

- 1) Educational space; where the learning problem is assessed against player motivation and translated into learning outcomes.
- 2) Translation Space; where a simple narrative is constructed.
- 3) Design Space; where the learning outcomes are redefined as gameplay goals.
- 4) Engine Space; where the gameplay missions are formed to deliver the learning content.

In this chapter we show how the GeoThermal World game is designed following this process.

## 4.1 Educational Space

To recap, the goal of the work in Educational Space (Fig. 4.2) is to produce a set of learning outcomes that can be embedded into the game. This is done through the following steps:

1. Identifying the problem: Define the educational problem.
2. Purpose: Define the game purpose.
3. Motivations: Define the target audience (TA) motivations.
4. Form the learning outcomes: Define learning outcomes based on motivations.
5. Learning objectives: Define objective based on the learning outcomes.

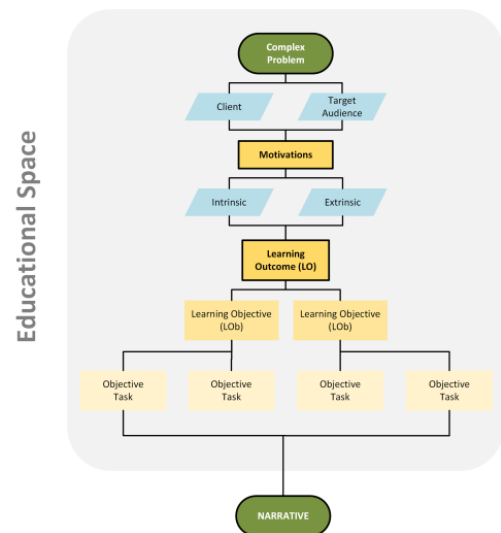


Figure 4.2 - Educational Space

The project was an interdepartmental collaboration between the HIT Lab NZ and the department of Geological Sciences at the University of Canterbury. The research was led by Dr Jacqueline Dohaney, a geologist and educational researcher, who is investigating novel approaches for geological study in the classroom. Dr Dohaney's research was supported by Mighty River Power, one of the largest hydro and geothermal power companies operating in New Zealand. The intent of building the GeoThermal World game was to recreate the valuable field trip experience of geologist training, and bring it to a platform that could be experienced in a classroom setting.

### 4.1.1 Identifying the 'Complex Problem'

The complex problem that underlies the need for building the gameplay is two-fold. Firstly, for a university geothermal field trips are costly, resource intensive and involve risk to students, due to the active nature of a geothermal area. However, they are also essential for students to gain practical experience of working with an active geothermal resource. Figure 4.3 shows an image of one of the annual field trip sites; Orakei Korako, currently visited by University of Canterbury students each year, and located near Rotorua in North Island, New Zealand. Secondly, Mighty River Power expressed concern that graduate geologists lacked awareness of balancing the challenges of working in an ecological and environmental manner with the economic requirements of corporate reality.



Figure 4.3 - GeoThermal field trip site

To address these issues the concept of *GeoThermal World* was proposed, so that through playing a computer game, the geothermal resource could be brought to the students. This would enable undergraduate/postgraduate geologists to become immersed in a virtual geothermal environment. A virtual world delivers the experience and complexities of geothermal geology, and offers geothermal exploration through safe, realistic, and engaging

gameplay. The game would also be able to incorporate some of the workplace issues into the playing experience, that are of concern to Mighty River Power.

#### 4.1.2 Defining the Purpose: Client and Target Audience

The project client was the Department of Geological Sciences, who were acting to bring new teaching methods to a topic that is very much a practical subject. This view was represented through the project collaborator and primary researcher, Dr Dohaney. The secondary stakeholder and client was Mighty River Power, who are one of the main employers of young geothermal geologists. They supplied geothermal experts to consult on the creation of a realistic geothermal resource.

Our target audience (TA) for the project comprised level 3 and 4 Geology, Geography, and Engineering Geology students at the University of Canterbury. It was our intention to bring the game into the classroom as a supporting resource for enhancing field trips and contextual knowledge of geothermal energy resources and practices.

#### 4.1.3 The Motivations

The client motivations focused on a game that enabled geologists to ***comprehend the world of Geothermal energy in a safe and engaging environment***. This was the clients' intrinsic motivation and guided the educational strategy of the game, by providing the context for the game's direction.

The clients' extrinsic motivations were the educational requirements that the game design must meet to serve its purpose.

Educational requirements included:

- To provide students with a visually accurate re-creation of a real-world Geothermal field showing the complexities of geothermal geology and exploration.

- To create a fully immersive free-roaming desktop virtual environment that would be safe, realistic, and engaging.
- To provide an authentic representation of field Geothermal and geology tools.
- To incorporate a gameplay system where students could learn about the balance between environmental and corporate realities.

The client side motivations provided a framework for the structure of the game and its educational content. However, the gameplay must be driven by the target audience's motivation or it will prove unappealing and fail to meet the clients' needs.

To establish the students' motivational drivers, Dr Dohaney undertook a survey of geology students at the university. They were asked the question: 'What would motivate you to do your job, and be good at your job'? In response, they were asked to give a level of agreement on the statements listed in Table 4.1. There were a total of seventy three respondents.

The statements were collated by score into 'Main' motivations and 'Supporting' motivations. Main motivational statements were those that gained fifty percent or more; those are numbered 1-4 in Table 4.1. The remaining statements; those below fifty percent, were aligned as supporting motivations. They were used to provide clarificational context in support of the four main motivational statements.

Table 4.1 – Percentage of responses to the motivational statements

Statements	%	Motivation Type
1. I like field geology and working outdoors	65%	Intrinsic
Supporting motivation: I like science and solving scientific problems	48%	Intrinsic
2. I just want to make money for the company and for myself	56%	Extrinsic
Supporting motivation: i want to be a good employee and beat the other companies looking for geo thermal	31%	Extrinsic
3. I just want to explore something new that has never been discovered	54%	Intrinsic
Supporting motivation: I like science and solving scientific problems	48%	Intrinsic
Supporting motivation: I want to make my first discovery (i.e. drill the first successful hole) and be a success	42%	Intrinsic/ Extrinsic
4. I want to develop a green resources and help save the planet	51%	Intrinsic/ Extrinsic
Supporting motivation: I like science and solving scientific problems	48%	Intrinsic

The geology students primary and intrinsic job motivation was their attraction and enjoyment of field work, at 65%. The second closest motivator was the desire to make money for themselves and the company. This is an extrinsic motivator and had 56% agreement. Close behind that, at 54%, was the desire to explore something new and undiscovered. This again is an intrinsic motivation. The final and most aspirational motivation, at 51%, was the desire to develop green resources and help save the planet. This is a mixed motivation as the development of resources is an extrinsic part of the intrinsic motivation to save the planet.

Together, these motivations informed the design scope of the game world. From the designers' perspective client motivations would be met through the details and 'features' of the 'virtual world environment', and TA's motivations would be met through engagement with the environment as directed by the 'gameplay strategy'.

#### 4.1.4 Learning Outcome and Objectives

The author, in her designer role worked closely with Dr Dohaney to reach a learning outcome that would guide the development of the gameplay. The learning outcome emerged through aligning client and target audience intrinsic motivations. The clients' intrinsic motivation; *where geologists comprehend the world of Geothermal energy in a safe and engaging environment*, provides the opportunity for the TA to experience their intrinsic motivations; *undertaking fieldwork, being outdoors, exploring and helping save the planet*. The learning outcome was formed through consideration for both of these motivational perspectives.

**Learning Outcome:** After playing the game the geology student should be able to apply a systematic and conscientious approach to geothermal exploration.

With the learning outcome agreed, the next step was to provide a framework of learning objectives to support the student in achieving that outcome.

The client extrinsic motivations; a list of the educational requirements to be met in game (see section 4.1.3), supplied the framework for the features and content of the environment. They provided the parameters that informed the learning objectives. The learning objects and subsequent related tasks, are the educational objectives that the gameplay must meet for the student to achieve the desired learning outcome. They define the educational aspects that the player should experience in the game world.



**Learning Objectives:**

1. Exploring the environment and Characterising Hot springs.
2. Getting land Access, Identifying Anomalies (from geophysical, and geochemical datasets), Creating (synthesizing data into ... ) a 2D model.
3. Drilling and Drilling Impacts.

**Objective Tasks:**

1. Taking measurements and recording data.
2. Characterising geothermal features.
3. Identifying geophysical anomalies.
4. Identifying chemical anomalies.
5. Identifying temperature anomalies.
6. Identifying surficial feature anomalies.
7. The student drills and explores conservatively.
8. The student selects an area to explore based on minimal complications from stakeholders, and environmental concerns.

**4.2 Translation Space**

The purpose of the translation space is to take the motivations, learning outcome, learning objectives and objective tasks, and translate them into an acceptable narrative. An effective narrative allows our TA, the geology student, to engage with the complex problem and learning outcome from a perspective that supports their intrinsic and extrinsic motivations. Figure 4.4 provides a recap of the Translation space in the SPP.

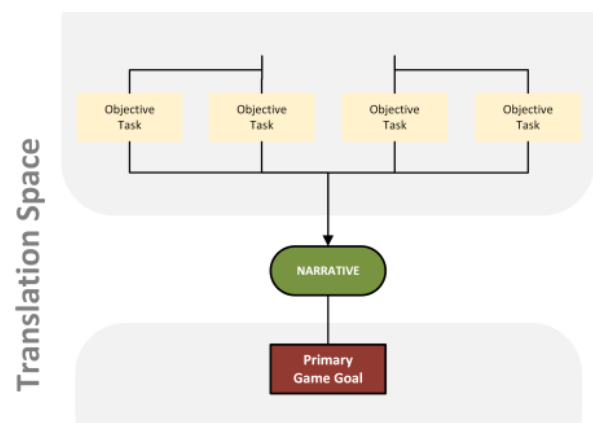


Figure 4.4 – Translation Space

**4.2.1 Narrative overview**

The purpose of the narrative is to provide a vehicle that supports the TAs intrinsic and extrinsic motivations. In this way it guides the gameplay experience and interactions within the game world. It is the method by which the learning outcome and learning objectives are embedded with the context of the gameplay. In this way it leaves the gameplay free of the need for overt references to the educational content.

As previously described in section 3.3.2, “To establish narrative we can begin to think in terms of our motivations and how they lead to the gameplay goals. Gameplay goals take three forms and these goals should reflect as strongly as possible the client’s and TA’s motivations. The goals act to drive the gameplay progression. These gameplay goals categories are:

- Aspirational/long-term Goals (intrinsic).
- Mid-range goals (intrinsic/extrinsic).
- Short-term immediate goals (extrinsic).”

Table 4.2 illustrates the process undertaken when exploring some of the possible narrative scenarios that could provide an effective interpretation for supporting the TA’s motivations within the gameplay. The exploration attempts an analysis of TA motivations contextualised by the gameplay goal categories listed above. These narrative scenarios are based on the responses to the motivational statements shown in Table 4.1.

Table 4.2 - Possible story narrative and their links to motivations and game goals

Narrative scenarios	
1. Geologist trying to find a Green energy resource. (A.k.a. save the planet!)	<i>a. <b>High level altruistic goal</b> and underlying narrative motivator, the ultimate prize/ perfect win state.</i>
2. Geologist who is keen to explore all the volcanic and geothermal features.	<i>a. <b>Primary motivator</b> of the player at a base level: The desire to get out in the field. Game is then very reliant on the environment to fulfil this desire.</i>
3. Young geologist trying to make his/ her first discovery.	<i>a. An <b>immediate goal</b> that provides motivation for the primary motivator and the high level goal. Also fulfils short-term intrinsic goals of professional recognition and acclaim.</i>
4. Geologist trying to make \$ for the company.	<i>a. An <b>immediate goal</b> which supports the intrinsic desire to make discoveries and gain recognition and acclaim. Money is also a provider of feedback as it is a way of keeping score and judging how well they are progressing.</i>
5. Geologist trying to balance socio-economic issues with economic issues.	<i>a. <b>Longer term game goal</b> that will develop in difficulty as the gameplay progresses. Can lead to Epic win/ Epic Fail state.</i>
6. Geologist competing with another company.	<i>a. <b>Not to be pursued in this game.</b></i>

Before a final decision on the narrative direction, the learning outcome is further explored for its narrative value. The deconstruction of the learning outcomes was taken from the perspective of the TA. This approach aided the alignment of client needs with TA's motivations from a gameplay point of view. Table 4.3 illustrates the deconstructive thought process undertaken.

Table 4.3 - Deconstructing the learning outcome from a gameplay perceptive

**Learning outcome;** the **Geology student** should be **able to apply** a **systematic** and **conscientious** approach to geothermal **exploration**.

**Geology Student;** is the target audience and therefore will be the model for the Player Character. Should be able to choose male or female but as game is played in FPS style the PC will not be seen.

**Able to apply;** achieve through the design of the gameplay skills and tasks. Delivered in a Quest/mission based scenario, with reward, achievement and feedback loops.

**Systematic;** take a scientific approach to the skills and task they are required to do as the geologist character

**Conscientious;** behaviour encouraged through the balance of environmental concerns (save the planet goal) and economic constraints of drilling for hydrothermal energy (Money). This factor brings in a narrative tension that reflects the real world situations that geologist face.

**Exploration;** is key to learning how to read surficial features from which experience and understanding can develop so that better choices can be made. Exploration is a key motivational factor for the target audience.

The results from this scenario and learning outcome analysis led to the formation of a simple narrative and plot scenario. These provided the background context to the gameplay world. The simple narrative and plot provided the design context around which to build the gameplay.

#### 4.2.1.1 GeoThermal World Narrative

The simple narrative chosen to guide the gameplay of the GeoThermal world game.

“A young Geologist directly out of university lands an exciting new job mapping a ‘green’ (i.e. grassroots, no previous drilling) geothermal prospect. The company has sent them out on their first field assignment. The young geologist feels attached to the landscape, and excited that they get to work independently on their first job. They feel that discovering a geothermal resource here would greatly benefit the local community economically. The geologist sees themselves as

a guardian of the landscape (following the principles of Kaitiakitanga<sup>7</sup>), and a successful sustainable resource could help benefit other communities across the country if this goes well. It might even have a positive impact on the global energy budget, avoiding environmental impacts if an effective sustainable system can be discovered and developed. The young geologist would gain recognition and acclaim as their discovery would financially benefit the company, providing a well-paid job, promotion and recognition of their work within the scientific community.”

#### 4.2.1.2 Plot Scenario

The game takes place in a fictitious area known in-game as Ashford, New Zealand. The project is a ‘greenfield’ geothermal resource, which means that no major drilling or geophysical surveys have been undertaken, making the ‘resource’ unknown. The player is going in blind, and there are many hotsprings, mudpools, and other surficial features at the surface to collect data from.

The geologist ‘player’ is introduced to the game world through a helicopter flight. It opens with the player flying around the geological features that provide a contextual aerial view of the topography, before landing at the field location to meet their game guide, Hamish. While flying, a voice over narration introduces the game world and level goals. “The challenge is to explore the untouched volcanic and steaming landscape of the ‘Kāpura Project’<sup>8</sup> in New Zealand, and to provide scientific data to your company. You must balance the economic and environmental impacts in order to succeed.”

### 4.3 Design Space

The Design Space (Fig 4.5) is where the learning content having been filtered through a narrative is now mapped into gameplay. It comprises of four basic steps.

1. Re-form the learning outcome as the primary game goal.
2. Re-form the learning objectives as level goals supporting the narrative structure.
3. The objective tasks become gameplay tasks seen through the narrative lens.
4. Filter the tasks into skill stages as outlined in the SPD model

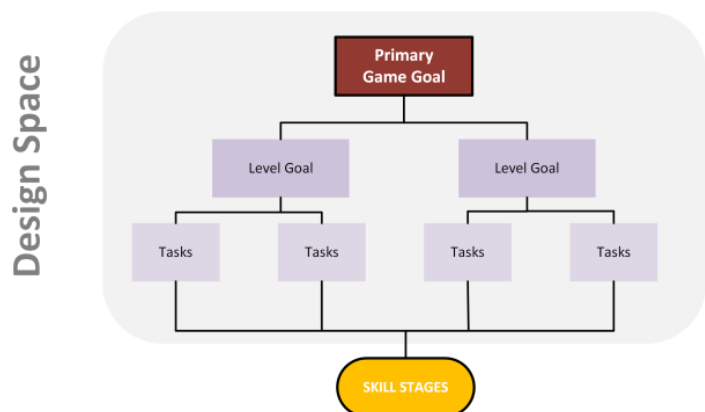


Figure 4.5 – Design Space

<sup>7</sup> [http://www.marinenz.org.nz/documents/Marsden\\_1992\\_Kaitiakitanga.pdf](http://www.marinenz.org.nz/documents/Marsden_1992_Kaitiakitanga.pdf)

<sup>8</sup> The Kāpura Project’ is a fictitious project constructed to support the gameplay

*Geothermal World* is an Educational Game based on a mixed game style of Role-Playing-Game (RPG) and Strategy. The game will be in First Person (FP). The game is set on and around a fictitious, young, active volcanic centre. This terrain is based upon the real-world setting of Mt Putauaki (see Fig. 4.6). Relevant topography will be added in the form of geothermal landscape features. Political information will also be added to this environment; such as towns, rivers, lakes, roads, rail etc., with as much or as little of this as required to fulfil the educational progression and motivation of the players.

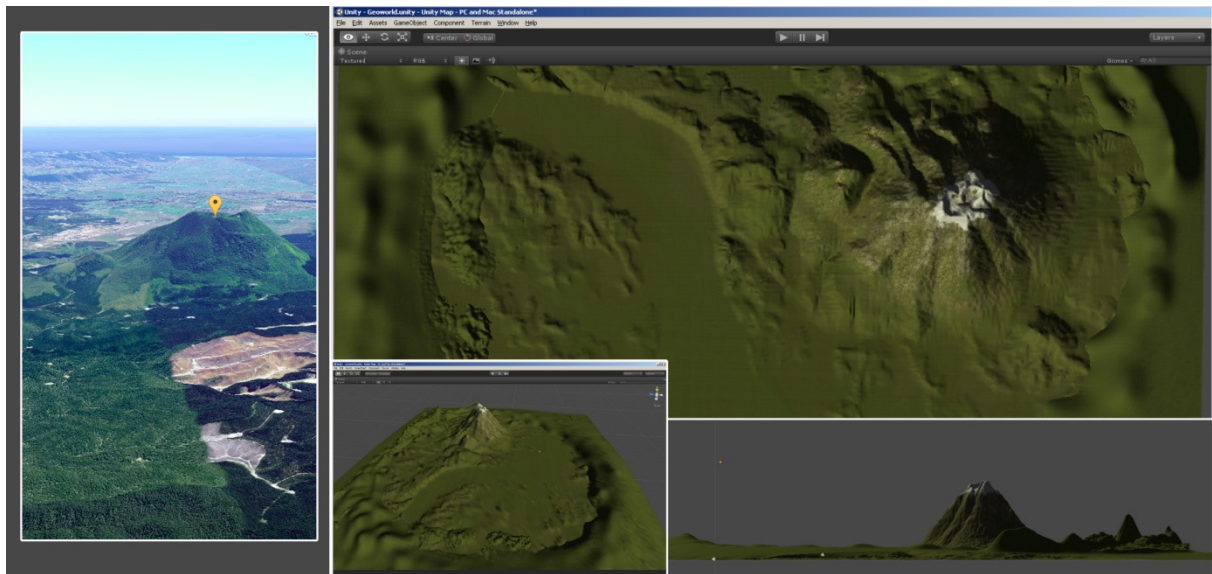


Figure 4.6 - Digital Elevation Map (DEM) of Mt Putauaki (left) recreated inside the Unity game Engine

### 4.3.1 Primary Game Goal

The first step is to reform the Learning Outcome as the primary game goal. The learning outcome stated that *“After playing the game the geology student should be able to apply a systematic and conscientious approach to geothermal exploration”*. The Translation Space provided the narrative context and plot Scenario which guided the reforming of the learning outcome as a gameplay friendly challenge.

#### Primary game goal:

*“The challenge is to explore the untouched volcanic and steaming landscape of the ‘Kāpura Project’ in New Zealand, and to provide scientific data to your company. You must balance the economic and environmental impacts in order to succeed.”*

With the gameplay narrative and goal set it was then possible to map the level goals and tasks. Dr Dohaney, the geological expert and project client, oversaw the interpretation of the learning outcome to game goal so it continued to meet the geological sciences educational requirements. This was also true of the decisions for mapping the gameplay levels to the learning objectives and objectives tasks.

### 4.3.2 Level Goals and Tasks

Here learning objectives are reformed as level goals that support the narrative structure. The game goals are mapped directly from the learning objectives and objective tasks outlined in the Educational Space (section 4.1.4). In Table 4.4 the three Learning Objectives (right) become the primary game goal of each level (left). The Objective Tasks (right) are then assigned to each of the gameplay levels (left) based on their level of difficulty. The gameplay levels and the assigned tasks are matched to the level of difficulty expected in the three Phases of Skill Learning; cognitive, associative and autonomous, as outlined by Fitts & Posner's (1967) Skilled Performance theory.

Table 4.4 – Comparison of Game Goals and Tasks to the Learning Objectives and Tasks

Gameplay Goals	Objectives
<p><b>Level 1: Cognitive phase (Early)</b></p> <ul style="list-style-type: none"> <li><b>Goal:</b> Explore the environment and Characterising Hot springs</li> <li><b>Tasks:</b> <ul style="list-style-type: none"> <li>Take measurements and record data</li> <li>Characterising the geothermal features</li> </ul> </li> </ul> <p><b>Level 2: Associative phase (Intermediate)</b></p> <ul style="list-style-type: none"> <li><b>Goal:</b> Getting land Access, Identifying Anomalies (from geophysical, and geochemical datasets), Creating (e.g. synthesizing data into...) a 2D model.</li> <li><b>Tasks -</b> <ul style="list-style-type: none"> <li>identify geophysical anomalies</li> <li>identify chemical anomalies</li> <li>identify temperature anomalies</li> <li>identify surficial feature anomalies</li> </ul> </li> </ul> <p><b>Level 3: Autonomous phase (Final)</b></p> <ul style="list-style-type: none"> <li><b>Goal:</b> Undertake drilling and assess drilling Impacts</li> <li><b>Tasks:</b> <ul style="list-style-type: none"> <li>the student drills and explores conservatively</li> <li>the student selects an area to explore based on minimal complications from stakeholders, and environmental worries</li> </ul> </li> </ul>	<p><b>Learning Objectives:</b></p> <ol style="list-style-type: none"> <li>Exploring the environment and Characterising Hot springs</li> <li>Getting land Access, Identifying Anomalies (from geophysical, and geochemical datasets), Creating (synthesizing data into ... ) a 2D model</li> <li>Drilling and Drilling Impacts</li> </ol> <p><b>Objective Tasks:</b></p> <ol style="list-style-type: none"> <li>Taking measurements and recording data.</li> <li>Characterising geothermal features.</li> <li>Identifies geophysical anomalies.</li> <li>Identifies chemical anomalies.</li> <li>Identifies temperature anomalies.</li> <li>Identifies surficial feature anomalies.</li> <li>The student drills and explores conservatively.</li> </ol>

#### 4.3.2.1 Level 1 Gameplay Strategy

The primary game goal with the level goals and tasks created a plan that outlined three gameplay levels. Due to time and funding limitations the decision was taken to concentrate efforts on realising the Level 1 goal to *‘Explore the Environment and Characterising HotSprings’*. To map the detail of Level 1 the ‘Design Space’ cycle was reiterated. Table 4.5 summarises the gameplay goals’ Level 1. The original level 1 goal becomes the ‘Primary Level Goal’ (top) which is then further broken-down into a number of Levels goals (left) which in turn have a set of gameplay tasks (right).

Table 4.5 - Gameplay goals for Level 1 development

<b>Primary level Goal:</b> Explore the environment and Characterising Hot springs	
Goals: During this level of game-play, students...	
Level Goals	Task Description:
<b>1. Become familiar with game-play</b>	<ul style="list-style-type: none"> <li>• Introduction into the spatial environment (terrain, visual features)</li> <li>• Introduction to manoeuvrability (how to walk, User Interface functions, camera angles)</li> </ul>
<b>2. Identify surficial features</b>	<ul style="list-style-type: none"> <li>• Hotsprings, geysers, mud pools, landscape (trees, mountains, rocks) and their dangers takes photos, touches, (scalds!)</li> </ul>
<b>3. Measure surficial features with Tools</b>	<ul style="list-style-type: none"> <li>• Acquires, or is given the geological tools to measure chemistry, visual aspects, and other properties</li> <li>• List of tools: Camera, Temperature gauge, pH conductivity meter, Sample vial (to assess the water chemistry)</li> <li>• How-to use tools (what each tool does)</li> </ul>
<b>4. Characterize surficial features</b>	<ul style="list-style-type: none"> <li>• Stores this information in a useable way (locations of photos)</li> <li>• Map features</li> <li>• Students should be able to apply a label to the hot-spring that is helpful for characterising the spatial environment</li> <li>• Do they go to the analytical lab to get the results of the chemistry?</li> </ul>
<b>5. Summarise the data</b>	<ul style="list-style-type: none"> <li>• Review notebook data to create as summary of the geothermal feature including a chemical classification</li> </ul>



Extensive research was undertaken between the client and designer to develop a realistic geothermal resource that accurately reflected real-world geothermal sites. The map in Fig 4.7 shows the full scope of the geothermal areas to be implemented into the 3D environment. The red dotted line encloses the gameplay area of level 1. The area enclosed by the solid pink line denotes the Sapphire pools geothermal feature. This is the active set of gameplay features that the player will interact with during Level 1 gameplay. The star represents the starting location for the game.

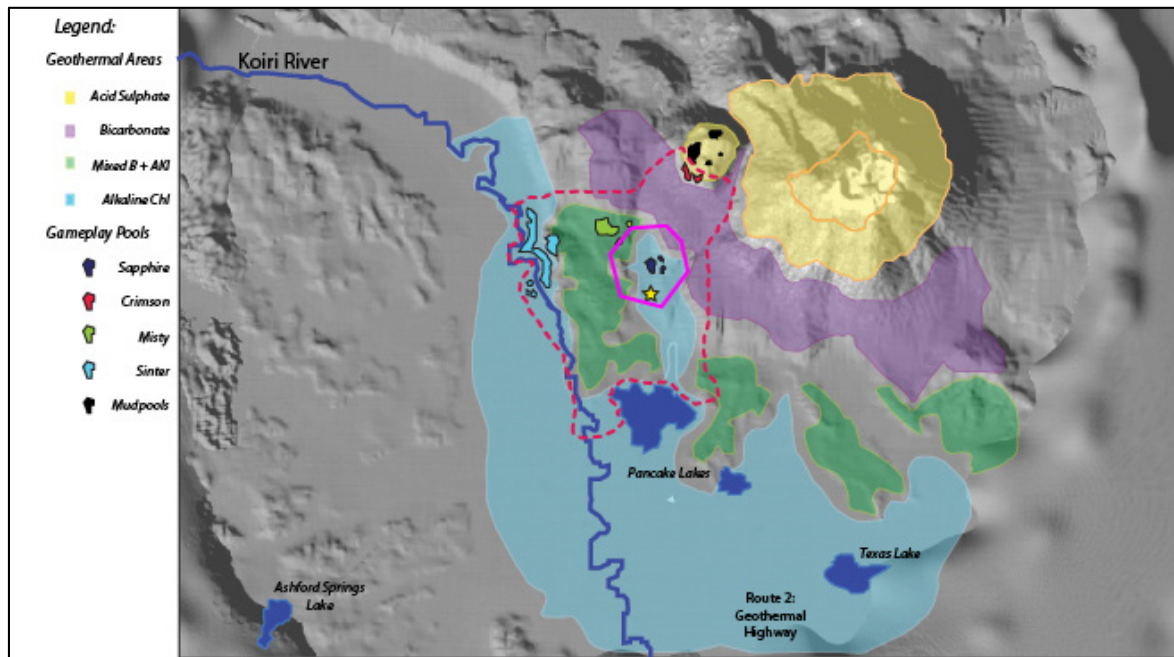


Figure 4.7 – Geothermal/geological features of the game world

### 4.3.3 Gameplay Features Supporting Gameplay Tasks

In the design cycle, the production of the game environment was progressed so that when the gameplay missions were ready for engine implementation the game world would be pre-set with all the supporting gameplay features. These features supported the level 1 tasks; of taking measurements, and recording data that enables the characterising of the geothermal features. This proved to be both technical and time intensive production work.

The student geologist's immersion into and acceptance of this virtual world lay in the creation of an environment that they could believe in. It had to be realistic in appearance, both in terms of landscape features and vegetation, but also in the look and feel of the liquid features. These included lakes and a river, and particular care was taken over the 'water system' for the geothermal pools. It also had to provide the geothermal tools and a geologists notebook for recording data. All of these features had to

be integrated into a user interface that supported smooth interactions. The remainder of the section details their development.

#### 4.3.3.1 Geothermal Pools

The geothermal pools are the focus of the gameplay and therefore had to reflect the chemical composition of the water in their look and feel. They had to show vent systems indicating the source and direction of flow in the pool, and an indication of heat, through gas and steam effects. To achieve this an adaptive water system was commissioned. The water editor could be used to change colour and opacity to create the effect of different chemical compositions. It also incorporated a bump mapping effect that could be altered to create ripple effects on the surface indicating the speed and flow directions. Combined with this was a system of particle effects employed to indicate heat levels and the vent outlets under the surface. The look and feel of the pools was critical to reflecting the real world. They had to support the student's enjoyment of the field trip experience, and meet the precise teaching requirements of a highly visual and practical subject. The pool feature had to provide realistic feedback about the environment that would be directly relatable to a real-world situation. Figures 4.8 to 4.12 show the main gameplay features of level one, the Sapphire Pools.



Figure 4.8 - A real world geothermal pool

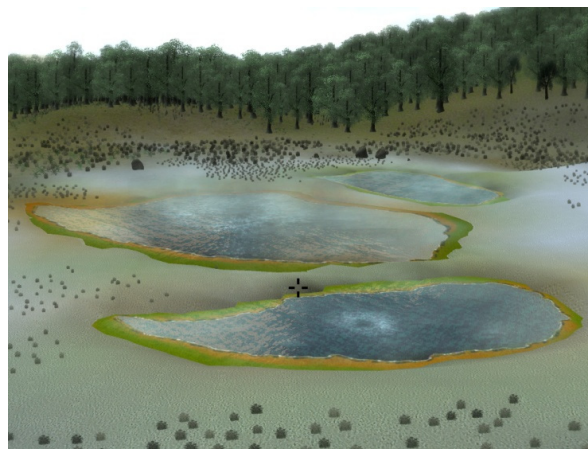


Figure 4.9 - Game world geothermal 'Sapphire' Pools

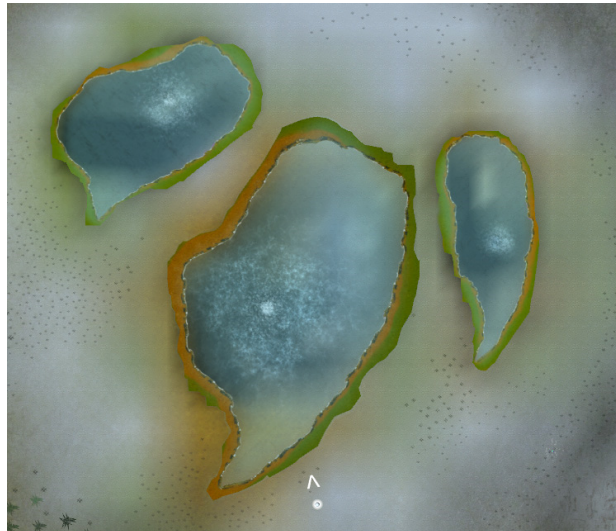


Figure 4.10 - A top view of the Sapphire Pools showing the vent locations and depth of the pools



Figure 4.11 - Close-up of the vent system and algal ring



Figure 4.12 - View illustrating the water's transparency, reflectivity and steam cloud effects

#### 4.3.3.2 Geothermal Tools

For the students to engage with the process of characterising the geothermal resource a range of tools were replicated for their use. All the tools had to function in a manner that replicated a real-world situation, supporting transferable knowledge of their practical use. The tools provided for the student players were;

- A camera for creation of a photographic record of the features.
- A conductivity and pH meter for taking readings of the pools chemical composition.
- A GPS unit for recording location data, in conjunction with a temperature probe and a water sampling kit.

Figures 4.13 and 4.14 provide screenshots of two of the gameplay tools.





Figure 4.13 - In-game camera



Figure 4.14 - In-game conductivity meter

#### 4.3.3.3 Geologist Geothermal Notebook

With the geothermal features and tools created, in-game the student was given a digital geologist's field-notebook with which to record their observations and measurements. This notebook was critical in bringing the experience of a field trip to life. The notebook was specifically designed to meet the requirements of the level 1 learning objectives and tasks. The notebook provided a systematic process for the player to record and order their individual gameplay data. It was their reference point to aid memory and order their in-game learning process. One page of the notebook collated all the information that the geologist could record at the geothermal resource. The layout of the notebook tied all the information together to aid comprehension. Fig. 4.15 shows the note-taking directive provided by Dr Dohaney, and acted as guiding principles for the design of the notebook feature.

**Table 3.1: Primary Learning Goals for Note-taking Lesson**

After participating in the field note-taking activity, the students will be able to...	
Goal 1	Locate themselves on a map, recording the relevant location information
Goal 2	Make and record visual observations at a geothermal hot spring.
Goal 3	Draw and annotate sketches in order to illustrate the overall and detailed features of the geothermal hot spring
Goal 4	Take measurements as a group (e.g., Conductivity of the waters) at a geothermal hot spring
Goal 5	Perform goals 1-4 in order to fully characterize a hot spring, recording it into their geologic notebooks.

Figure 4.15 - Shows the note taking directive provided by Dr Dohaney for the design of the in-game Notebook book

Dr Dohaney, Brogt, & Kennedy, (2014) attest that *'Making observations and recording these observations into a field notebook is among the primary skill sets that a novice geologist must acquire for their professional and academic careers. These observations are the data that a geologist uses to make hypotheses and record changes in the landscape from one location to the next. These core geoscience skills are needed in academia and the workplace.'* Therefore the design and function of the

notebook was key to building the students' cognitive schema of geothermal exploration as presented through the different tasks undertaken in the gameplay missions. Post-play this digital notebook could be output as a html file so the students in-game observations could be assessed by a tutor and discussed with the student.

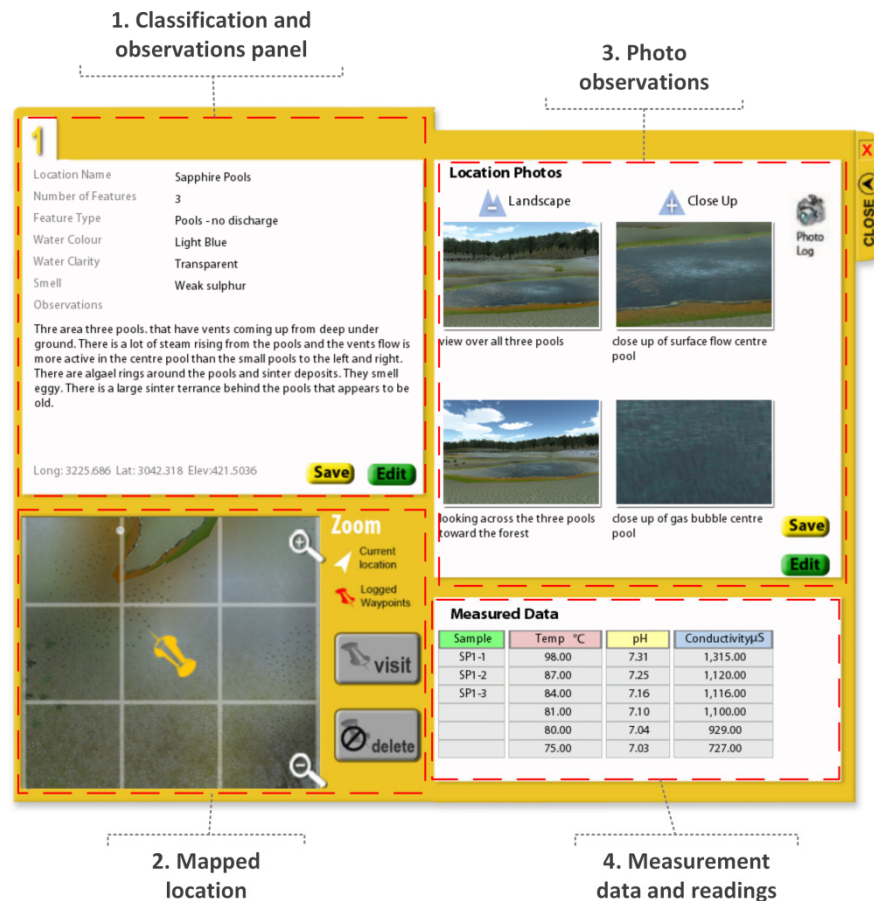


Figure 4.16 - Screenshot of the in-game student field notebook.

The digital notebook (Fig. 4.16) orders the information that the student needs to record into four areas:

- (1) **Classifications and Observations Panel:** This is the main area where classification and observation data is entered. There are numbered tabs at the top of each page which order pages specific to the location. A yellow number on the tab shows that it is active and selected. The second part offers a dropdown list of possible classification answers. In this way it acts like a multiple choice question. The observation field is blank and it is left to the student to write as little or as much observation data here as they see fit. There is a save and edit feature that un/locks the field for editing.
- (2) **Mapped Location:** This field of the notebook records location information sent from the in-game GPS. It shows a map of the area with a yellow pin on the map marking a logged waypoint.

This waypoint is pinned to the location, which shows the location area for the data recorded on the page.

(3) Photo Observations: This page has fields for placing photographs taken with the in-game camera. Below each image is an editable field where the student can write observations related to that image.

(4) Measurement Data and Readings: This final field is where all the measured data is recorded. This data is sent from each of the tools and creates a record of the measurements and readings taken at the pools.

#### 4.3.3.4 User Interface

The user interface was minimalist so as not to interfere with the players' intrinsic motivation of exploring the environment. The user interface shown in Fig 4.17, comprised a mini-map feature aligned to compass points that provided an overhead view of the players' direction. Table 4.6 provides the outline of the user interface features and functions.

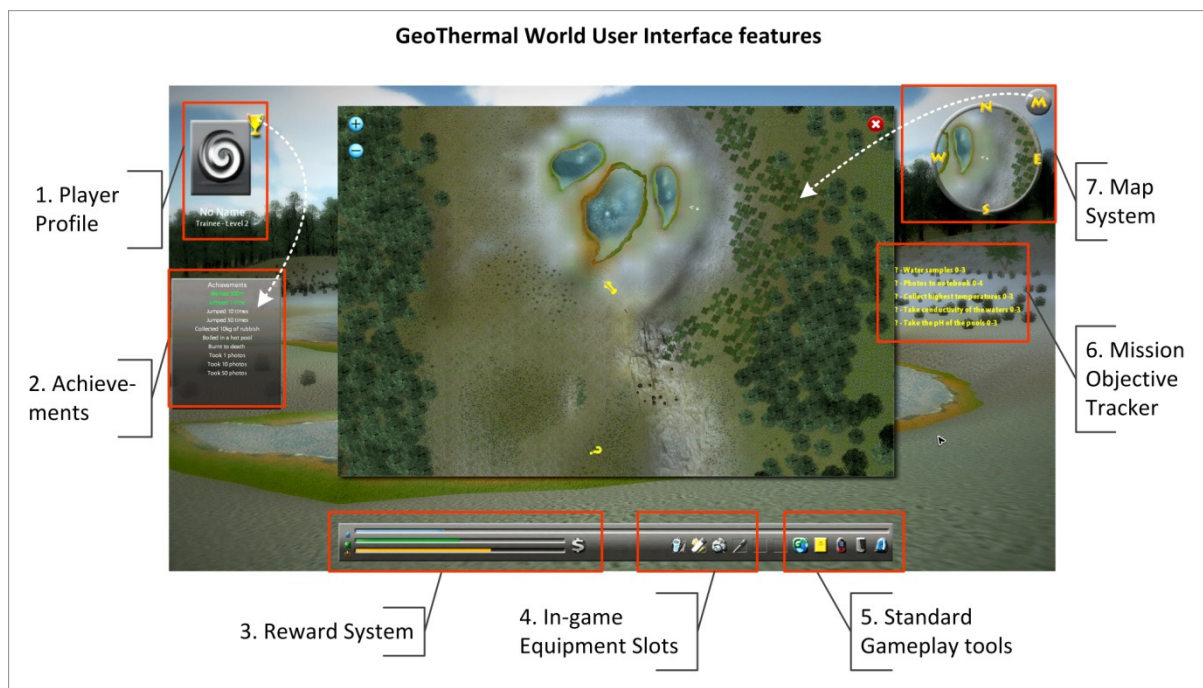


Figure 4.17 - GeoThermal World User Interface functions

Table 4.6 - An outline of the User Interface features and functions

1	Player Profile	The player profile provides information on the character type chosen by the player. Different character types have different strengths and weaknesses, and support the range of extrinsic and intrinsic values the player brings to the game. The player profile also tracks the player job title which changes when the player receives a promotion for successfully completing gameplay objectives.
2	Player Achievements	Player achievements log. Displays all active and completed achievements. Achievements are a secondary system of activities that reward player exploration and discovery.  They are not directly linked to the learning tasks, but act as additional, fun, and positive reinforcement mechanisms.
3	Reward System	The reward system is a points-based system that is linked to Mission Objectives and outcomes. <ul style="list-style-type: none"> <li>• The blue bar tracks Experience Points (XP). It shows how far from 'levelling-up' their abilities and unlocking new gameplay missions.</li> <li>• The green bar tracks environmental success through eco-points. These are award for missions that are weighted as environmentally positive.</li> <li>• The orange bar tracks commercial success through com-points. These are award for missions that are weighted as supporting the corporate company goals.</li> </ul>
4	In-game Equipment Slots	The toolbar has a number of empty slots where the player can place equipment that they will use during gameplay. For level 1 gameplay tasks at the Sapphire Pools the player has a conductivity and pH meter, a water sampling kit, a digital camera and a temperature probe.
5	Standard Gameplay tools	These are the set of items that the player will need to access during every level of play. From right to left there is the: <ol style="list-style-type: none"> <li>1. Menu - Save and exist functions</li> <li>2. The geologist Field Notebook shortcut</li> <li>3. The GPS shortcut</li> <li>4. The Mission Log – which is depicted in-game as a smart phone. This holds all of the mission details for the players' reference.</li> <li>5. Inventory - All the players' equipment that is mission specific is stored here in the geologists backpack</li> </ol>
6	Mission Objective Tracker	This is a mission objective feedback mechanism. It tracks each mission objective providing feedback on task progression. It is a shortcut format for the mission system.
7	Map System	The circular mini-map shows player local location and compass direction. The mini-map can be expanded to provide a large map view (centre of the image in figure 4.13). The large map view can be scrolled and zoomed in and out. This helps with player orientation and supports discovery.

### 4.2.3 Skill Stages

The Final step in the design space is the mapping of the content into Skill stages. Skill stages are the method the SPD and SPP models use to structure the gameplay content (see section 2.3.2). Fig. 4.18 illustrates the structure of a skill stage.

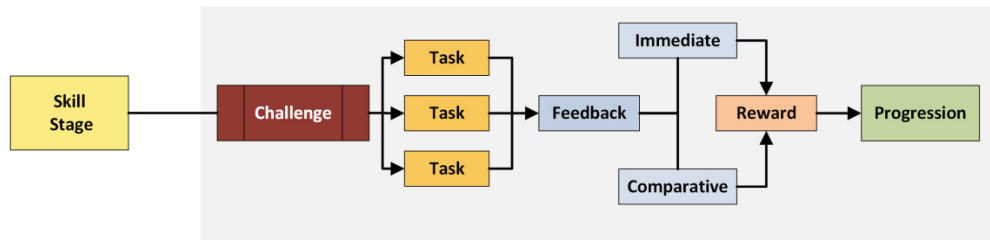


Figure 4.18 – Skilled Stage mapping taken from the SPD model

In *GeoThermal World* the gameplay revolves around Level 1. In terms of the Phases of Skill Learning, Level 1 falls within the cognitive phase. In the context of the complete gameplay plan, Level 1 constitutes the tutorial level of play. Each skill stage that comprises Level 1 also progresses the player through a similar, three phase cycle.

The initial intention for level 1 was for five skill stages, each exploring geothermal features of increasing complexity under the framework of the level goals:

- Skill stage 1 – Sapphire Pools (Alkaline chloride).
- Skill stage 2 - Chemical Classification, both mapped to the cognitive phase.
- Skill stage 3 - Crimson Pools (Acid Sulphate).
- Skill stage 4 - Spatial distribution of all features, mapped to the Associative phase.
- Skill stage 5 - Reporting, culminating in the utilisation of all the learnt skills, mapped to the Autonomous phase.

For the project to be completed on time and within budget, while meeting the requirements of a playable level, the design and production focused on the delivery of Skill stage 1, the Sapphire Pools educational content. To realise this, the gameplay missions were mapped out according to the parameters of the Engine Space.



#### 4.4 Engine Space

The Engine Space (Fig. 4.19) provides the method for structuring the gameplay missions within the game-engine and within the game-world. It takes the Skill Stages of the Design Space, which house the learning outcomes and objectives, and applies them in terms of gameplay missions.

The Mission System strategy provides a visualisation of the logical structure guiding the gameflow; it aids translation of the gameplay concepts for the engine-build. In this way we have a consistent logical process for ordering the gameplay's levels goals. This logical structure provides consistency of experience for the designer in structuring the learning into gameplay missions, and for the programmer in structuring the mission into playable code. For the player this

delivers a logical structure that can be quickly learnt and anticipated, and allows them to concentrate on the task at hand without having to break their gameflow to decipher how to progress.

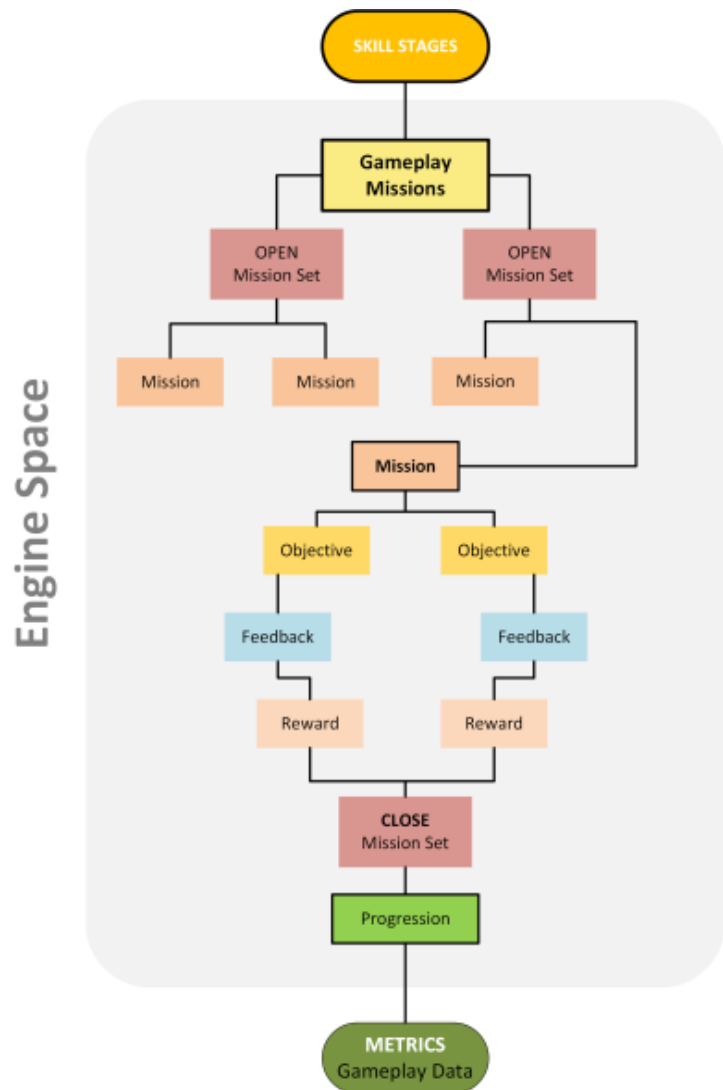
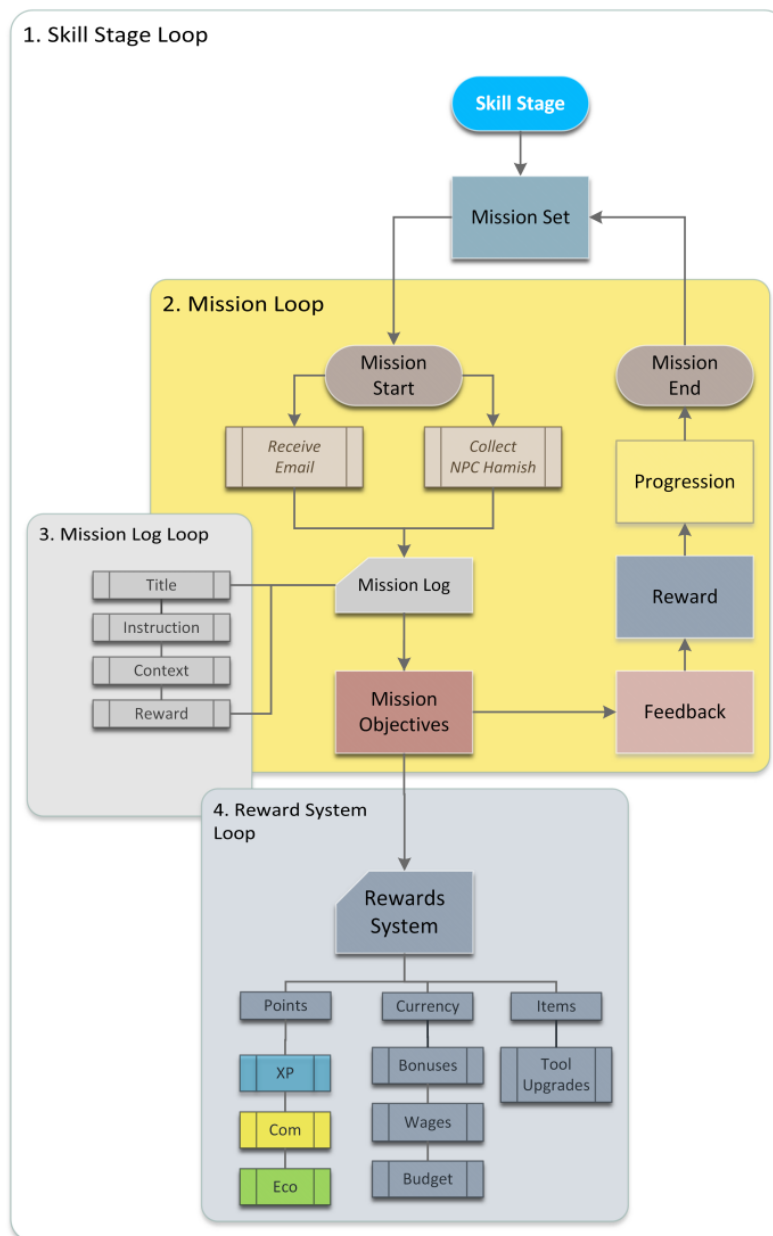


Figure 4.19 - Engine Space

Time and funding were limited in the development of *GeoThermal World*, with only 90 days available for the gameplay engine development before testing with the target audience. Attention was focused on development of the Level 1 plan through the building of the Sapphire Pools Mission Set. The Mission Set would take the player through all five of the gameplay goals of the Level 1 gameplay strategy listed in Table 4.5, (section 4.3.2.1). This Mission Set falls with the cognitive phase of skill learning and would be built as a tutorial level.

### 4.4.1 Mission System

A pre-engine mission system framework, shown in Fig. 4.20, was developed for structuring the level goals. It created a system for increasing complexity of the Phases of Skill Learning (Fitts & Posner, 1967).



#### 1. Skill Stage Loop:

This framework is designed to structure the goal-focused skill based tasks that are expressed in Skill Stages. This approach structures gameplay through the Mission Set framework of the SPP approach.

#### 2. Mission Loop:

Houses the different learning goals, breaking them down into Missions, which in-turn breaks down into Mission Objectives.

#### 3. Mission Log Loop:

Provides the context and instruction for the Mission Objectives, and clearly structures information the player will need to complete the mission. The objectives are where the player completes the sets of in-game tasks that carry a range of rewards.

Figure 4.20 - Pre-engine mission structure plan

#### 4. Reward System Loop:

The reward system, in combination with environmental and Non-Player Character (Hamish) interactions provide feedback to the player on their success and failure.

Success is measured through continued progression i.e. unlocking new Missions, receiving new tools, or further character development.

#### 4.4.2 Rewards and Feedback

The reward system in *GeoThermal World*, displayed in the Reward System Loop, (No.4 in Fig. 4.20), supports learning and motivation through a carefully integrated system of Points, Currency and in-game Items. Points are awarded for Experience (XP); these are awarded through the mission system and are linked to achievement of mission objectives. These are shown via an XP bar in the interface. The game also teaches the need for balance between corporate and environmental concerns. This is expressed through rewards of Eco and Com points. Missions are weighted to be either ecology (Eco) based or commercially (Com) based so the player explores this balance through their actions. This system is again shown via a visual interface indicator. Currency rewards take the form of project budgets, wages and bonuses for good work. Items can also be awarded on mission completion; where all awarded items enhance the player experience directly by supporting progression. See table 4.7 for an example of achievement objectives and the XP rewards.

There is also a secondary 'Achievements' system that allows players to complete tasks not directly linked to the more overt learning goals embedded in the mission system. This system rewards and supports the player through the provision of fun/ mini game experiences that build up points. These points can be used to trade for Items or Eco/ Com points, giving the player a 'get out of jail' card if their gameplay style has led them to fall behind in a required area. The purpose of achievements is to provide a fun and motivational boost in support of the more complex learning in the mission objectives.

#### 4.4.3 Mission Set 1 – Sapphire Pools (SP)

Table 4.7 summarises the applied information, structured by the SPP approach, for the GeoThermal World game concept. We see the relationship between; the high level learning outcome, the means by which that outcome will be achieved through the gameplay goals, and their mapping into a set of gameplay missions. The missions are well supported through the careful development of the gameplay world's geological and geothermal features. Mission set 1 is focused on exploring and characterising the alkaline chloride Sapphire pool features.

Table 4.7 - Structure of Mission Set 1 – Sapphire Pools

EDUCATIONAL SPACE			
Learning Outcome	After playing the game the geology student should be able to apply a systematic and conscientious approach to geothermal exploration.		
DESIGN SPACE			
Primary Level Goal	Explore the Environment and Characterising Hot Springs		
Objective Tasks	Take measurements and record data Characterising the geothermal features		
Gameplay Goals	1. Become familiar with game-play 2. Identify surficial features 3. Measure surficial features with Tools 4. Characterize surficial features 5. Summarise the data		
ENGINE SPACE - Gameplay Action			
Mission Set	Sapphire Pools	<i>Mission Code</i>	SP
Mission	Objectives		Reward
SP1 - Explore Area	1. Explore area around pools 2. Find Hamish’s Glasses	400 XP	Level Up – Promotion 1
SP2 – Email	1. Read Email from the boss 2. Speak to Field Manager (Hamish)	200 XP	
SP3 - Locate pools	1. Locate Observation point at pools 2. Map Location using GPS 3. Write observation notes in Book	600XP	Level Up – Promotion 2
SP4 - Equipment	1. Choose equipment from Hamish 2. Accept remaining missions	200XP	
SP5 - Take measurements	1. Take water samples 2. Take Photos 3. Take water temperature 4. Take Conductivity 5. Take pH	1000XP	Level Up – Promotion 3
SP6 - Summary log	1. summary of Descriptive data 2. summary of Measured data	600XP	Level Up – Promotion 4
Level reward	Flight to Top of Volcano	Mission Set complete	

#### 4.4.4 Gameplay Mission Logic

With all the tools and features of the game world in place the mission system was implemented into the engine. A full set of mission dialogue scripts and interaction and feedback requirements were written, providing instructional and contextual information for the player. The mission scripts were implemented into the game engine through a content editor interface. The editor interface reveals the mission system structure as shown in Fig. 4.21. This provided the designer with the ability to edit the mission content and game world. Having this level of control allowed the designer to optimise the gameflow interactions of each mission.

An in-engine system was put in place to implement the Sapphire Pools Mission Set (Table 4.7). Figure 4.21 summarises the overview of the engine mission logic system. The logic follows the open/ close mission set of the SPP approach. In the game-world experience the player can interact with and explore the gameplay environment without ever having to engage with a mission. This is the free-roaming aspect of self-determined discovery (Deci & Ryan, 1985) that was one of the primary motivators for our geology students. This free roaming world experience, termed ‘Sandbox’ (Kelly, 2014b), allows the player to experience the world without rules or restrictions. It is the players’ choice to interact with the gameplay structure, by approaching the NPC who delivers the missions and provides the structure to the experience. The Mission system is a four step hierarchical system as shown in Fig. 4.21.

The first step in **1.Mission System**, watches for player interaction with the NPC. A ‘mission open’ visual signal is shown in the game world in the form of a ‘?’ next to the NPCs location. This lets the player know there is an active interaction point. When interaction is initiated the system calls the first Mission Set. When the mission set is complete it will either initiate the next Mission Set or return the player to sandbox mode. The **2.Mission Set** is the controller for the gameplay missions. It houses all missions related to that particular gameplay set. It acts in the same way as the Mission System in initiating the next mission or ending the Mission Set. The third step is the **3.Mission** structure itself. This is where the gameplay dialogue and instructions are presented to the player. It does this through NPC interaction, and through replication into the mission log smart phone tool. The mission logic provides an option for the player to accept or decline a mission at this point. Declining a mission ends the cycle and returns the player back to sandbox mode. The Mission section also controls the feedback and rewards for mission completion. All this takes place through the interaction with the NPC in the game world. The deepest level of the structure is in the logic for implementing the **4.Mission Objectives**. A Mission can house a number of objectives, and to complete a mission the player must complete all related objectives.

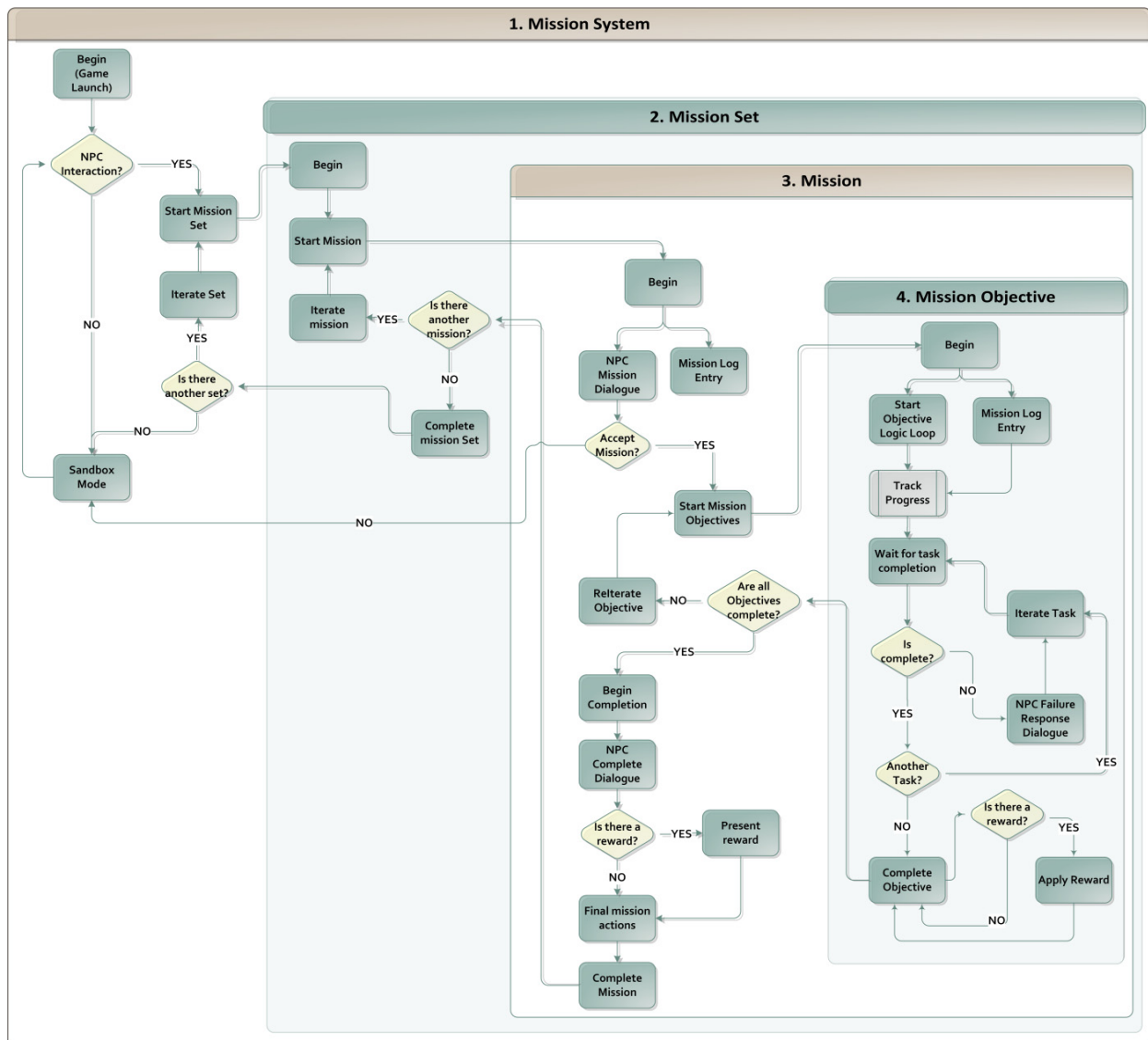


Figure 4.21 - GeoThermal World - Engine mission system logic sequence

An objective might have four tasks that the Mission Objective logic logs as constituent parts of the whole objective. Some objectives carry a feedback reward which are triggered during the mission when selected objectives have been achieved or partly completed. These feedback rewards display as the visual and audible delivery of XP points and occur during the gameplay. This form of reward provides feedback on progression and helps to keep the player motivated.

Some mission objectives are hidden from the player. For example, these objectives are only checked by the engine when checking for a player/ NPC interaction that triggers a mission complete message. Some player-facing objectives carry further detailed information on a task that the player must be aware of. These additional sets of instructions and contextual information are added to the Mission Log smart phone.

Additionally, each objective is tracked via an onscreen shortcut, which provides the player with a quick reference point to judge their goal progression. This onscreen tracker is most useful when the player is undertaking multiple objectives containing multiple tasks. When all mission objectives are complete the player must return to the NPC to close the Mission. On return, a completion message is triggered which provides feedback on the mission outcomes, and is followed by an invitation to undertake the next mission. If an objective is only part finished an incomplete dialogue message is triggered directing the player to complete the mission before it can be closed.

#### 4.4.4.1 Mission Logic Screenshots

Figures 4.22 to 4.25 provide a set of screenshots that illustrate the connection between the mission logic, mapped out in Fig. 4.21, and the game engine perspective of the designer and player. In these examples we follow the logic of Mission SP1 – Explore the area (Table 4.8).

Table 4.8 – Outline of Mission SP1

Mission	Objectives	Reward	Progression
SP1 - Explore Area	<ol style="list-style-type: none"> <li>Explore area around pools</li> <li>Find Hamish's Glasses</li> </ol>	400 XP	Level Up – Promotion 1

Game Engine View of Mission SP1

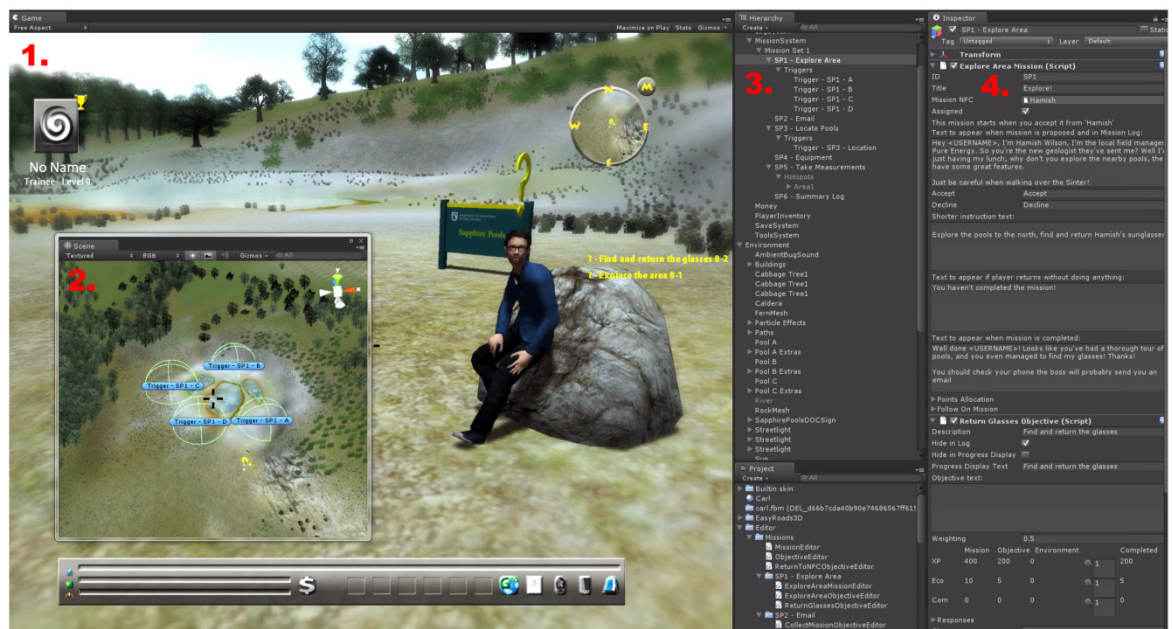


Figure 4.22 - Designers view of the game world as seen in the Unity3D game engine



In this image we see the designers' view of the gameplay world through the game engine interface. This interface is where the mission parameters are edited. The mission system interface is on the right, and the two views of the game world are on the left.

1. The 'Game' view showing the perspective of the Player.
2. The level editor 'Scene' view from the designers perspective.
3. The 'Hierarchy' view showing the Mission system hierarchy for Mission Set 1 - Sapphire Pools (SP).
4. The 'Inspector' view showing the designers view of the Mission SP1 and its Mission Objectives.

## 2. Mission Set

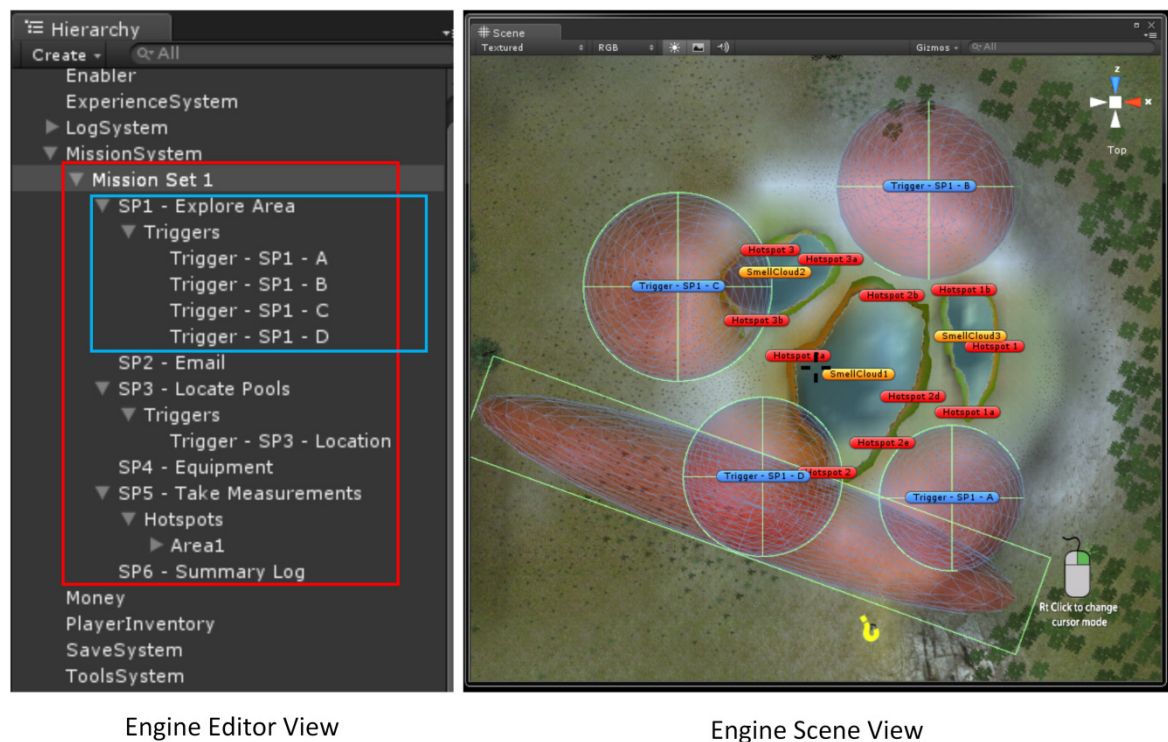


Figure 4.23 - Engine and engine scene view of Mission Set SP1

Highlighted in red on the left of the editor view we see the Mission Set structure with the list of Missions it holds. Highlighted in blue is mission SP1. On the right hand side we see a screenshot of the Sapphire Pools gameplay area. In this image you see the complete set of interaction points for the whole of Mission Set 1. This shows the trigger points and hotspots that will activate during the gameplay through player interactions. The blue box on the left highlights the trigger points for Mission SP1 – Explore the Area.



## 2. Mission

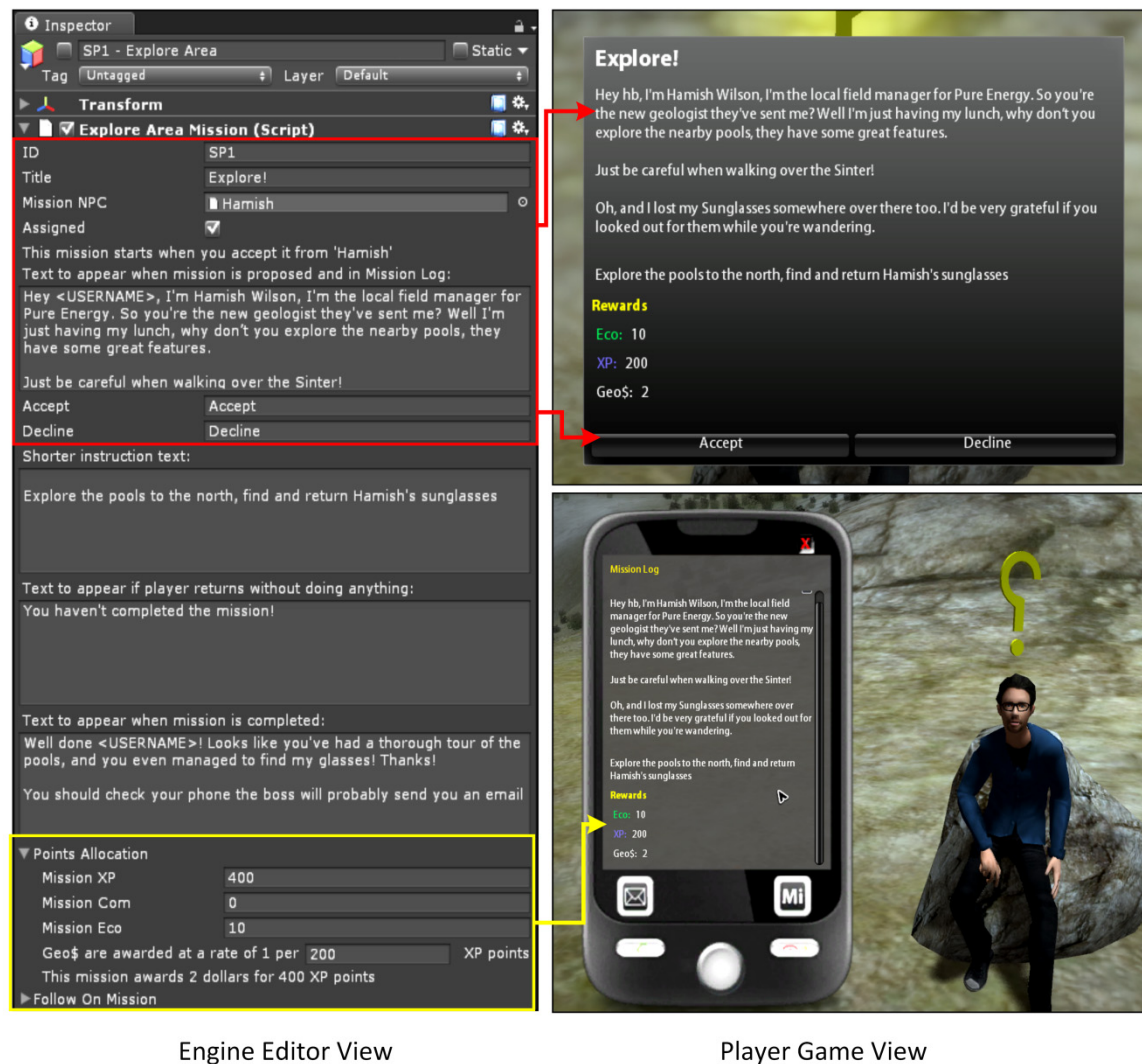


Figure 4.24 - Engine and game view of Mission SP1

On the left we have the engine editor view, where the designer inputs the dialogue and mission log scripts for mission SP1. On the right you see the output of this editor from the player viewpoint.

The red box on the left contains the mission text. This text is relayed to the player through the NPC interaction mission box (top right) that details the mission. It also provides the player with the opportunity to accept or decline the mission. The second image (bottom right) shows the accepted mission displayed in the Mission Log's 'smart phone'. The yellow box on the right of the image details the reward system of the points allocation. These reward points are displayed in both the NPC mission interaction box and the mission log. The mission interaction box is only available when 'talking' to the NPC and will close if the player walks out of range. The Mission log however, is carried with the player and can be opened and read wherever the player is situated.

## 4. Mission Objectives

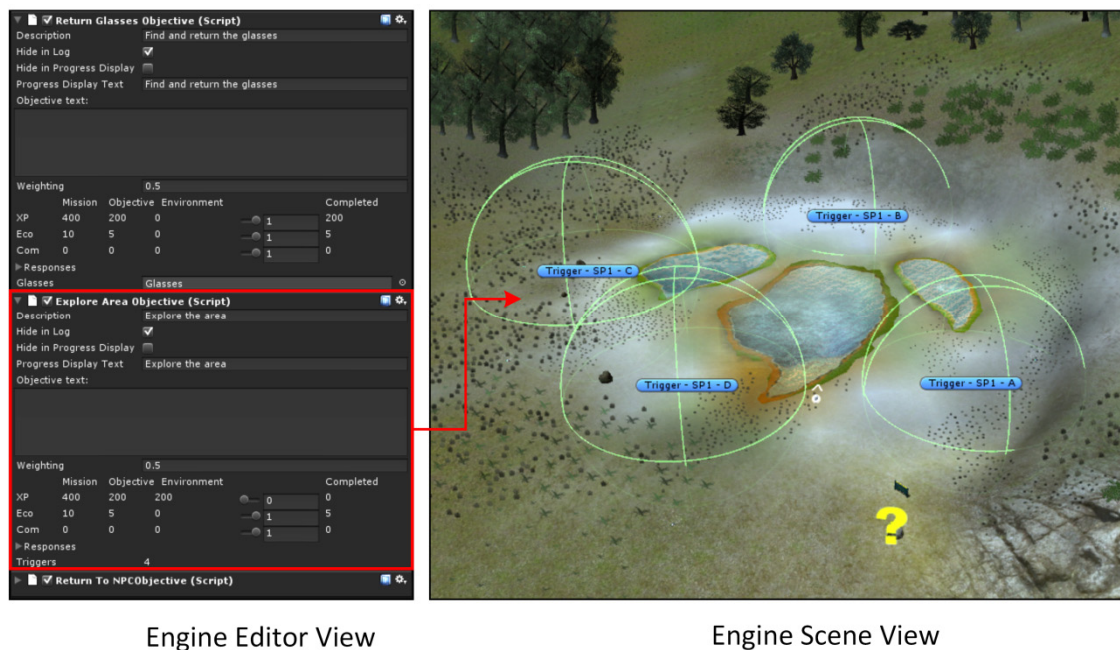


Figure 4.25 - Engine and engine scene view of Mission Objectives of mission SP1

The Mission SP1 has two player facing objectives, these are (1) Explore the area around pools and (2) Find Hamish's Glasses. The mission Objective editor (left) highlighted in red shows the Explore the Area objective. Attached to this objective is a c# script that tracks the player progression across the four trigger points, seen in the image of the Engine Scene View (right). To achieve this objective the player must walk around the hotpools. Their path must intersect with all four trigger-point domes to meet the mission parameters of exploration of the area. The Objectives editor has a reward points weighting system. This determines how many points are awarded for completion of this particular objective from the overall points' allocation for the Mission.

## 4.5 Discussion and Conclusion

*GeoThermal World* is in essence, an immersive sandbox recreation of a geothermal landscape. It has a volcano at its heart, and geothermal features to be explored. The client's motivation was to bring the field-trip to the student, and the student's motivation was to be out in the field experiencing and discovering the landscape. This meant the design was visually, geologically and experientially accurate, and provided the 'physical' interactions with the landscape that the geologist could expect from real fieldwork. The player was provided with a 'first person' experience so they could be immersed with the experience of exploring within the landscape.

These aspects were plotted out through the Educational Space of the SPP approach; where the learning outcome and objective led directly to the gameplay goals. The designer spent time with geothermal experts who created detailed maps of the geothermal fields to be recreated in the game. The intent was for the game-world experience to be as immersive as possible by being as close to reality as could be designed within engine, budget and time limitations.

The SPD skilled performance principles (Bradshaw, 2007; Fitts & Posner, 1967) provided the starting point that focused the educational goals and structure. This led to an understanding of the client side 'complex problem' to be explored in the gameplay. The 'complex problem' fed into the building of the gameplay experience and game world. The gameplay experience was informed by, and supported, the motivations of both client and player.

The world expanse had to directly support the learning outcome and the objectives that would be undertaken in meeting the client side 'complex problem'. From the designers' perspective, having motivational sets from both client and TA enabled the contextualisation of the narrative. Through a clear narrative context the Learning Outcome and Learning Objective were embedded into the plot scenario. This provided the vehicle for the Learning Outcome and Learning Objective to be interwoven with the gameplay interactions.

The 'Design Space' was closely defined by the precise requirements of; creating a geothermal landscape, and putting geothermal features in place, ready for exploration. Knowing what we wanted to achieve based on the learning outcomes, and having a plan of the world through detailed maps, gave both client and designer the ability to translate the learning objectives into level goals, and to then virtualise them into the landscape.

The designer was provided with a list of all the tools required for the gameplay, and an understanding of how these were applicable to the gameplay strategy. This enabled the breakdown of the skill stage 1 objectives for increasing the player challenge and levels of difficulty. The Skill Stages and their interpretation into 'Mission Sets', were where the parameters for achieving Flow were established, as they govern the pacing of the challenges by following the conditions of 'three phases of skill learning' of a skilled performance. If these skill stages are paced well, and work in tune with the environment and gameplay features, then conditions for Flow state can be generated.

The notebook was key in tying the various aspects of the learning experience together. It was this gameplay feature that allowed the player to record their own personal experience, tying all the tasks together into one place where the player could review their personal content and edit as they saw fit.

The use of the mission system outlined in the 'Engine Space' of the SPP and experienced through the NPC, Hamish, provided the narrative support that contextualised the experience for the player. The games mission system provided the game-side implementation of the learning by pacing the skill stages challenges. It provided a simple and logical system for the designer to focus the player onto the gameplay tasks, rather than the player having to search in-game for the content.

The advantage of producing a mission structure, was in the provision of a clear framework for communicating development issues between client and designer, and this structure simplified the context of the design and build process. The SPD system of skill stages with a rewards, feedback and progress structure helped formulate the educational goals into real player experience. From a design perspective, pre-defining the mission structure before the mission system was implemented into the game-engine and gameplay enhanced communication between designer and programmer, who was coding the game-world interactions. This resulted in creation of a level editor in the game engine which the designer used to apply the gameplay's interaction parameters.

#### **4.5.1 Conclusion**

The development questions asked of this research are:

1. Can the SPP be followed as a design approach when presented with a real-world client problem?
2. Can the designer implement the learning outcome and objectives of the client into a gameplay system that can be built in a game engine?

At the conclusion of the design and development of GeoThermal World, the experience of using the SPP approach generated content that provided the opportunity for the students' intrinsic motivation to explore, while meeting the needs to the client for the world to be realistic and safe. With a sandboxed world, the player was provided with a self-determined choice; whether to just explore, and /or interact with the missions that would let them play the role of being geothermal geologist. The rewards system also supported opportunities for feedback on effort, aiding progress within the world.

It was found that the SPP approach had some crossover between the design and engine space which occurred around the Skill Stage mapping. The designer was working on two levels; one, in the Design Space to write the client side mission structure and content; and two, in translating these into the logical

mission structure of the 'Engine Space' for coding by the programmer. The engine space structure is a reflection of the skill stage structure preceding it. Therefore, the Skill Stage of the SPP should detail the conditions for mapping a skill stage more clearly.

In conclusion, the four spaces of the SPP approach; Education, Translation, Design and Engine act as a practical, guiding approach for translating a real-world client 'problem' into an effective gameplay environment. The use of motivation theories (Csikszentmihalyi, 1990; Deci & Ryan, 1985; Abraham H. Maslow, 1999) to define Learning Outcomes, Objectives and Tasks provides an acceptable framework for the structuring of a narrative, leading to the application of clear gameplay goals.

In answer to the second development question, it is possible for the designer to implement the learning outcome and objectives of the client into a gameplay system that can be built in a game engine. It is the use of Skill Stages (Bradshaw, 2007, 2010), supported by the application of Skill Performance theory (Fitts & Posner, 1967) which links the Design and Engine spaces. Ensuring that the SPP approach can provide the structure for mapping Mission Sets and their system of challenge, tasks, feedback and reward within a game engine, the implementation of the Mission Set structure into a game engine establishes a system that can be used to design player progression and gameplay goals.

The following chapter will outline the user study undertaken to test the gameplay experience and learning outcomes of '*GeoThermal World*'. This study will help address the third development question:

4. Will the games when complete meet the learning outcomes of the client through providing the Target Audience with an engaging gameplay experience that provides subject knowledge?

# 5

## GeoThermal World User Study

This chapter reports the outcomes of the user study for the GeoThermal World computer game. The study was a collaboration between the author and Dr Jacqueline Dohaney, of the Geological Sciences Department, University of Canterbury.

It explores the effective impact of the GeoThermal World computer-game against a baseline real-world field-based activity. This real-world data provides an exploratory basis against which the impact of the gameplay can be judged. The following text also details the process by which the third development question; *Stream b)* factors that focused on structured learning activities, were addressed:

Development question 3 – *“Will the games when complete meet the learning outcomes of the client through providing the Target Audience with an engaging gameplay experience that provides subject knowledge?”*

Student’s learning gains (knowledge acquisition) and perceptions of the activities (Flow) were collected and compared before and after the learning activity. Measuring knowledge acquisition levels and perceptions on Flow conditions can be used to establish whether a skilled performance was achieved. This can then be used to infer what or if any influence the SPP design approach has had on the outcomes. The game teaches basic geothermal concepts in the field of Geological Sciences by providing an inquiry-based approach where the students learn important exploration skills.

### 5.1 Research Questions and Hypotheses

The aim of the study was to establish whether the gameplay's design supports a student's ability to perform skilled tasks and enable conditions for optimal experience known as Flow to occur. The study measured two aspects; knowledge acquisition and perceptions on Flow conditions.

We propose that If the design of the gameplay structure is sound then it should be possible to evaluate its effectiveness through testing levels of knowledge acquisition attained from undertaking the skilled tasks of the activity. The level of acquired knowledge indicates the degree to which a skilled performance was achieved (Bloomfield, et al., 2010; Kooloos, et al., 2012). Similarly, if the gameflow (Salen & Zimmerman, 2003, p336) design led to feelings of engagement with the game experience then

this can be inferred through measurement of participant perception on engagement with Flow conditions. Flow is the description of an optimal experience where the 'experience is autotelic, the person is paying attention to the activity for its own sake' (Csikszentmihalyi, 1990 p67).

### 5.1.1 Knowledge Acquisition

Since the effectiveness of a computer game designed in this way is an unknown (e.g. this is the first), its level of 'goodness' needs to be established. In Geology the established and favoured method of skill learning in geothermal exploration is the field-trip. To establish a useful baseline of data the skills taught during the field-trip matched those of the gameplay.

The research questions formed to investigate knowledge acquisition were:

1. Does playing inquiry-based videogame, versus traditional methods (closer to lecturing, or fieldwork) have higher overall learning gains?
2. Does the gameplay design support a skilled performance?

To answer these research questions we argue that the learning outcomes designed into the gameplay strategy by following the SPP approach should provide a framework for players to achieve a positive increase in knowledge acquisition. Therefore, the following hypothesis was formed:

**H5.1:** That a computer game simulation of geothermal field activities designed using the Structural Playability Process can support positive knowledge acquisition.

Testing the hypothesis should tell us whether a skilled performance was generated and to what level of skill.

### 5.1.2 Perceptions on Flow conditions

Alongside skill-learning the players should enjoy and become involved in the gameplay experience. To investigate the impact of the SPP-designed experience we measured the player's perception after taking part. Asking the following research questions allows us to explore the impacts of the designed experience.

1. Does playing in a realistic/authentic videogame impact student attitudes in a positive way?
2. What is the difference in the level of enjoyment in the learning experience between traditional (tutor or lecturer-controlled and modelled) as opposed to inquiry-style gameplay (self-determined; control over decisions and path)

The author argues that a game designed by following the SPP approach should produce an engaging experience (see chap. 3). To establish the validity of this argument this study will assess levels of

involvement with the computer game against exploratory baseline data. Baseline data was collected via the established and traditional, tutor-led field-trip method of teaching geothermal exploration. In the case of geologists, field work is seen as a favoured activity and this was true for the studies participants as there was 65% agreement that field geology and working outdoors was core motivator (see Table 4.1, section 4.1.3). Therefore it is relevant to measure the Flow experience of a field-tip to provide a baseline, against which inferences about the goodness of the SPP designed gameplay can be drawn.

Therefore, the following hypothesis was formed:

**H5.2:** That a computer game simulation of geothermal field activities designed using the Structural Playability Process provides an learning environment that promotes conditions for a state of optimal experience, otherwise known as 'Flow'.

Testing the hypothesis should tell us if the gameplay was enjoyable and involving and under which of the Flow conditions the involvement was strongest.

## 5.2 Design of the Experiment

The study was a between-subjects design and comprised of two testable conditions. The independent measures variable was the learning environment with the two treatments being *Game* and *Field*. These treatments had unequal populations. There were two dependant measures that took the form of a skills test and a perception on Flow conditions questionnaire.

### 5.2.1 Dependant Measure 1 - Skills Test

The experiment looked at the effects of the learning environment (how learning environment impacts learning) on knowledge acquisition. The dependent measure was determined by an exam of pre and post-test scores measured on a concept test of observational skills and tool use.

The level of knowledge acquisition was established through a normalised delta score of student learning gains. Hake, (1998) published a seminal work that provided education researchers with a sound metric that normalises each student's individualised learning 'change'. 'Learning gains' (commonly shortened to 'gains') are calculated by:

$$\text{Learning gains} = \frac{(\text{Post-test \%} - \text{Pre-test \%})}{(100\% - \text{Pre-test \%})}$$



### 5.2.2 Dependant Measure 2 - Participant Enjoyment on Flow Conditions Questionnaire

The experiment looked at the effects of the learning environment (how learning environment impacts enjoyment of learning) on Flow criteria for participant enjoyment. The dependent measure was determined through use of the adapted EGameFlow (Fu, et al., 2009) post activity questionnaire. Which comprised of 24 individual questions collated under 8 categorical headings. Perceptions on Flow criteria were measured on a 5 point Likert scale with (1) being strongly disagree and (5) being strongly agree and (3) being neutral. (see section 3.3.3.2 for the EGameFlow)

### 5.3 Participants

Our two study populations (field, and computer-game) were comprised of mostly 3rd and 4th year (Masters) Geology students, with a subset of non-geology science majors (e.g. Environmental Science, or Biology). The field group consisted of 32 subjects with 18 males and 14 females and the computer-game group had 12 subjects with 7 females and 5 males. The average age across both groups was 21 years. When analysing the skills test, 9 sets of participants' data from the field group had to be excluded due to incomplete pre/post skills test data or un-answered questions.

### 5.4 Methodology

The study was undertaken in two different settings: setting 1: Field geothermal activity, where students participated in a traditional field geology lesson in an outdoors, situated learning environment; and setting 2: Geothermal World Computer-game, where students explored a virtual environment.

**Setting 1 - The field study** (Fig. 5.1) consisted of approximately 60 minutes of activity at the beginning of a typical field trip day. This took place at the Hochstetter Pool at Orakei Korako, New Zealand on Feb 2nd, and 3rd 2012. The class was split up into two groups with 3 different instructors. The three instructors were briefed with a specific set of tasks and 'rules' to allow control of the content (i.e. how much and what kind of information was given) and context (i.e. how much reasoning and relationships are explored) under which the tasks were taught at the hot spring. See Appendix B.1 for a copy of the instructors' guidelines.



Figure 5.1 - The experimental setting of the Field condition

**Setting 2 - The computer-game** consisted of a 60 to 90 minutes gameplay session. It took place in a lab setting accommodating up to 5 students each with access to an individual PC. Each student had a comparable set-up comprising of a gaming ready PC with 3D accelerated graphics capability, a high resolution 24 inch screen; displaying full screen at 1680x1050 resolution, headset and standard keyboard and mouse. Video observations were recorded to follow the behaviour and user experience use during gameplay. The gameplay is designed to be self-explanatory, but students were instructed that they could ask questions of the researchers and other students in the room if they wished. This reflected interaction conditions of the field experience.



Figure 5.2 - The experimental setting of the Game condition

## 5.5 Study Parameters

To test the effectiveness of our computer game an experiment was developed where the learning objective defined for level 1 of the computer game could be replicated in the field. The students learning objectives in both environments were *‘to explore the environment and characterize hot springs’*. Within both environments the student tasks were *1) Taking measurements and recording data* *2) characterizing geothermal features*, (see section 4.3.2 for explanation of objectives).

To facilitate the collection of comparable data sets, each situation provided the students with the same set of learning tasks delivered in the same order of progression. In the field, learning tasks were introduced in situ at a geothermal site reflecting the starting situation in the computer game. In the field the students were informed they would be undertaking a tools-based activity, this provided a differentiation between the experiment activities and the other field activities undertaken on the same day. Both environments provided a central information provider. In the field the tutor provided the tasks, information and guidance. In the game the learning tasks and related guidance were delivered through interaction with a non-player character (NPC).

Both the Game and field situations had a set of core tasks that had to be undertaken. Table 5.1 displays the comparable learning tasks in order of progression. These are the core tasks on which knowledge acquisition was measured. Due to the different nature of the learning environments there were subtle differences between some of the tasks, such as in Measurements (a) between taking photographs and drawing sketches.

Table 5.1 - Comparable tasks between Game and Field required for meeting the learning objectives of exploration and characterisation

Task	Game Mission Version of the Task	Field-Trip Version of the Task
<b>1. Locating yourself in the environment</b>	Locate Pools Objective 1 – map location using GPS	Locate position on the map provided in the field notebook <ul style="list-style-type: none"> <li>A GPS reading (waypoint) is taken and pasted on to student to record in notebook</li> <li>Student to make a note on Map of their position</li> </ul>
<b>2. Making observations (a)</b>	Locate pools Objective 2 - write observations in notebook <ul style="list-style-type: none"> <li>Where are you in reference to other geographic features?</li> </ul>	Local Geographic features <ul style="list-style-type: none"> <li>Observe the local features</li> <li>Rivers, mountains, escarpments</li> </ul>
<b>Making observations (b)</b>	Locate pools Objective 2 - write observation notes in Book <ol style="list-style-type: none"> <li>Location Name</li> <li>Number of features</li> <li>Feature type</li> <li>Water colour</li> <li>Water clarity</li> <li>Smell</li> </ol> - General observations	Visually Describe The Feature <ol style="list-style-type: none"> <li>number of features</li> <li>The colour of the water.</li> <li>Describe the clarity</li> <li>Describe the activity of the pool.</li> <li>Do you see sinter?</li> <li>The odour or smell of the pools.</li> <li>- Students to make observations in your own words.</li> </ol>
<b>3. Measurements (a)</b>	Take measurements Take Photos <b>Instruction:</b> Add four photos from your photo-log to your notebook, a close-up shot and a wide view. Write descriptions of what is relevant in each image.  <b>Supporting Info:</b> Be sure to document the most important visual features. Photographing the close-up features is just as important as documenting the overall site.  Taking photos is similar to drawing sketches of a field site; it also gives other geologists a record of the activity of the geothermal area at this point in time. This helps in the monitoring of geothermal areas.	Draw Field Sketches of The Feature <b>Instruction:</b> While observing the features, it is good practice to draw (or take photos of) the feature that you see. Note close-up details, and general (overall details)  <b>Supporting Info:</b> Describing how (or documenting; photos) is good for illustrating the important aspects of the pool. This is relevant for the monitoring of pools (to note visual changes over time).  Point out the overall features (shape, discharge, colours). Students to <b>sketch</b> and <b>label</b> the features that they draw. Remind students to remember to use a scale All of the visually described data (ABOVE) like colour, presence and shape of sinter, algae colours and extent are all examples of features that are good to sketch.
<b>Measurements (b)</b>	Take water temperature	Take the Temperature of the water
<b>Measurements (c)</b>	Take pH	Take the pH of the waters
<b>Measurements (d)</b>	Take Conductivity	Take the conductivity of the waters
<b>Measurements (e)</b>	Take water samples	Take a sample, for chemistry
<b>4. Data Summary</b>	Summary log NOT AVAILBALE IN GAME	Complete the summary log

One of the key aspects of any field trip is for geology students to take field notes. As you can see from the previous chapter a digital field notebook was designed for the students to use in the computer game. The design and layout of this notebook was provided for the field-trip students in paper form. Both notebooks are shown together in Fig. 5.3. The authors co-researcher in Dohaney et al., (2012) argues that *‘making observations and recording these observations into a field notebook is among the primary skill sets that a novice geologist must acquire for their professional and academic careers. These observations are the data that a geologist uses to make hypotheses and record changes in the landscape from one location to the next’*. The notes in the field were not digital so the students were asked to draw field sketches of their environment observations, instead of taking photographs.

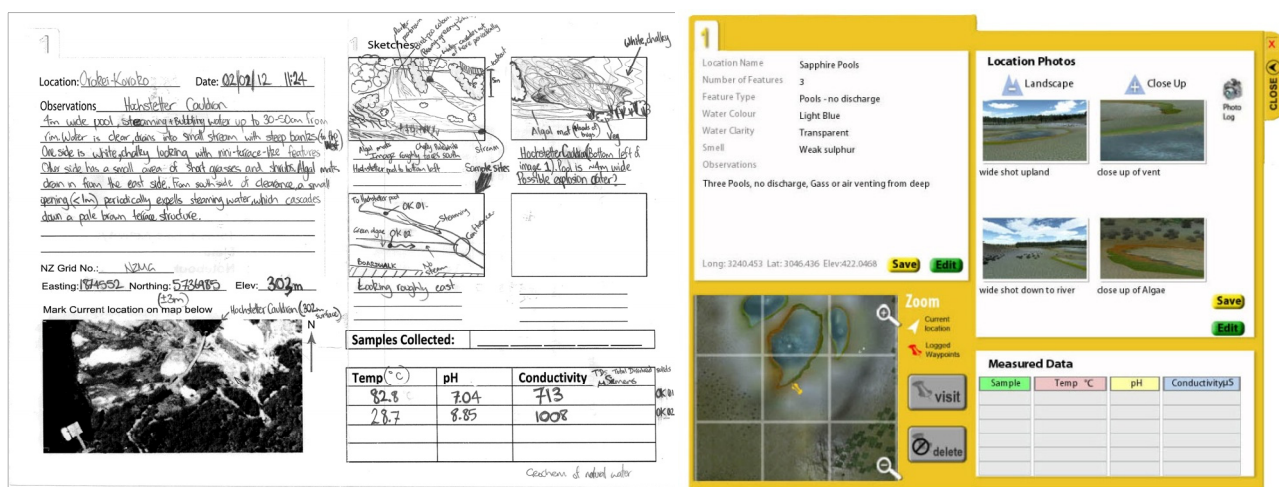


Figure 5.3 - A sample page of the field-trip paper notebook (left) compared with the digital game version (right)

## 5.6 Materials

Two sets of materials were developed to assess the dependant variables. These are described in the following text alongside the selected assessment methods that were used.

### 5.6.1 Knowledge acquisition

The knowledge acquisition skills test was devised by the author's co-researcher Dr. Dohaney, who is an expert in geological sciences.

The pre-post skills test was a paper-based test, designed and administered to assess the student's knowledge of observation and measuring skills.

- Question 1 was an open-ended, short-answer style question, consisting of two parts; (a) List types of visual observation data to be collected at a geothermal hot spring, (b) Provide the reasoning for each type of data. Question 1 made up the majority of the marks on the test with twelve correct observation types that to be noted. Each observation was awarded 0-1 mark for

listing each type (Question 1a.), and 0-3 marks for the reasoning provided (Question 1b.) for a total of 48 marks. This style of question, open-ended; short answer (Chan, 2009) was chosen purposely and allows us to probe specific student responses for awareness of items, and depth of response.

- Question 2 was comprised three multiple-choice questions (2 marks), it involved students locating places to safely and accurately take temperature and conductivity readings, on a hot spring diagram.
- Question 3 presented nine options when asking “which is NOT an effective method when sampling &/or visiting geothermal hot springs?” (1 mark)

Testing ‘conditions’ at Orakei Korako were not entirely controlled as it was given ‘in the field’, with some noise and visual distractions that come from being at a tourist location. However, in both studies all of the students were given as much time as needed to fill out the tests (most students completed them in approximately 15 minutes), and were not allowed to share their responses with others.

#### **5.6.1.1 Selected Assessment Methods - Knowledge Acquisition**

The learning strategy was designed using the SSP to meet the learning outcome ‘*to explore the environment and characterizing hot springs*’. The practical actions required to meet the learning outcome were, making observations supported through the notebook design and undertaking the tools based activities. The skills test was developed to measure the increase in acquired knowledge against the Learning outcome. The skills test was developed to match the skilled tasks of both learning environments.

- Question 1 of the test primarily measures the knowledge acquired from the activities in Task 2 - Making observations (a) (b) (see Table 5.1 for the details of the task components). The purpose of the notebook in both the game and the field environments was to support the recording of these observations.
- Question 2 measured the students understanding of spatial locations for optimal tool use for taking geothermal readings and measurements. This question measures the knowledge acquired during Task 3 – Measurements activities (a/e) (see Table 5.1). The questions asked were; which location would be the best for taking a (1) Conductivity reading (2) Temperature reading and (3) what is the white coloured material in the photo is most likely to be?. These

were three options from the five sets of measurement tasks the student undertook during the activity.

- Finally, Question 3 is a general question which assesses knowledge not acquired from undertaking a specifically task, but from experiencing the whole environment. It seeks to understand the degree of comprehension the student acquired while being immersed in a geothermal landscape.

The complete skills test and marking scheme for question 1 can be found in Appendix B.2 and 3

### 5.6.2 Perception on Flow Conditions

The EGameFlow (Fu et al., 2009) questionnaire, adapted by the author and given to participants directly after the activity was used to collect the participant's perception of the activity they had undertaken with the aim of establishing the level of participant enjoyment by measurement of perceptions on Flow conditions. Selected assessment method - Flow conditions Our questionnaire comprised of 24 individual questions collated under 8 categorical headings presenting 3 questions per category. Perceptions on Flow criteria for enjoyment were measured on a 5 point likert scale with (1) being strongly disagree and (5) being strongly agree and (3) being neutral. The questionnaire's purpose was to seek information on the 8 conditions for Flow alongside some features of computer game heuristics. The questions asked were applicable to both the field and game treatments of our study. It also included an overview category explicitly targeting enjoyment.

For the purpose of this study the element of 'knowledge improvement' was replaced with the new category of 'Enjoyment'. 'Knowledge improvement' was replaced as our skills test covered this category. The additional 'Enjoyment' category acts as a simple perception measure of participants' overall enjoyment level of the experience.

According to Fu, Su, & Yu, (2009) the EGameFlow scale has good internal consistency, with a Cronbach's alpha coefficient reported of .942 for the 42 items as a group. In this study the Cronbach's alpha coefficient was .872 for the 24 items as a group. Therefore, the adapted questionnaire with the additional category of Enjoyment also has good internal consistency.

All of these categories are related to conditions for generating a Flow state. The only purely game heuristic category assessed was Social Interaction which is not considered a condition for achieving Flow, and Enjoyment. See Appendix B.4 for the adapted EGameFlow questions.

## 5.7 Procedure

Each condition of the study had three stages: 1) Pre-activity measures for collection of baseline data; 2) the activity itself; and 3) post-activity measures. Prior to the study participants were first asked to sign a consent form which provided information about the studies purpose and gained permission for their data to be gathered. Ethics approval was received for the study prior to executing any data collection activity from the study participants. Ethical approach confirmation can be found in Appendix B.5.

### Pre-Activity

Participants undertook the skills test to assess their subject knowledge. Participants were instructed to answer the questions to the best of their ability, and ask the researcher if they needed help. Subjects were instructed not to discuss the contents of the test with the other participants. They were also reminded that it was confidential. Participants then undertook the pre-activity questionnaire that collected their demographics, academic background and work experience.

### Post-Activity

Participants repeated the same skills test after completing the learning activity. Once this was completed the participants undertook the post-activity EGameFlow questionnaire. The students were informed that the purpose of the questions was to establish their general perception to towards the day's geothermal hotsprings observation activity. They were informed that there were no wrong or right answers and that their personal opinion is what mattered the most. They were instructed to circle the statement that was felt to most closely represent their views.

For those who participated in the game condition a post-game interview was also held. This consisted of a set of open-ended questions that are designed to follow-up the experience and probe for deeper knowledge and experiences.

## 5.8 Results

The outcomes on Knowledge Acquisition showed there was a significant learning benefit through participation in both conditions, with no significant difference found between the learning gains.

Outcomes of participant perceptions on Flow conditions showed those who played the game left with a more positive perception of the experience than Field participants. The categories showing the most significant differences were in Challenge and Immersion for Game and Social Interaction for Field. In terms of enjoyment a strong relationship was found with Flow conditions and the Game experience.



### 5.8.1 Knowledge Acquisition

The delta for learning gains was calculated for each participant from an exam of pre and post-test scores measured through a concept test of observational skills and tool use. An Independent t-test examined the equality of means of knowledge acquisition between computer game and field trip.

Figures 5.4 and 5.5 compare the mean scores of the pre and post-test for each of the three questions for the conditions Field and Game.

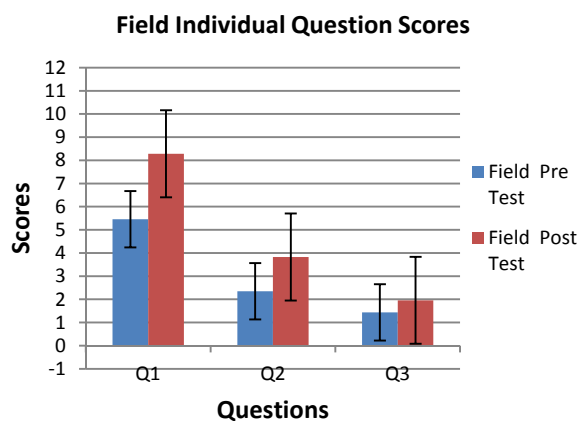


Figure 5.4 - Field Pre-Post test scores by individual question

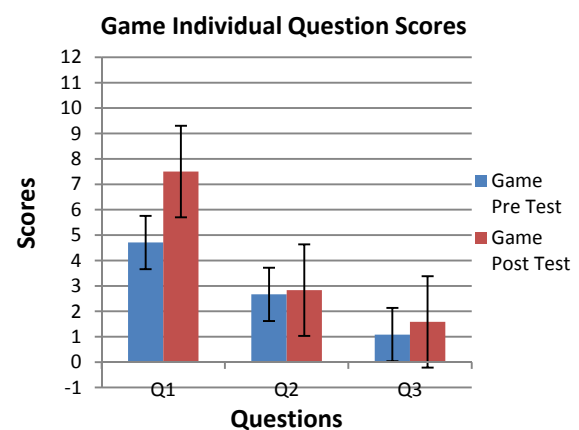


Figure 5.5 - Game Pre-Post test scores by individual question

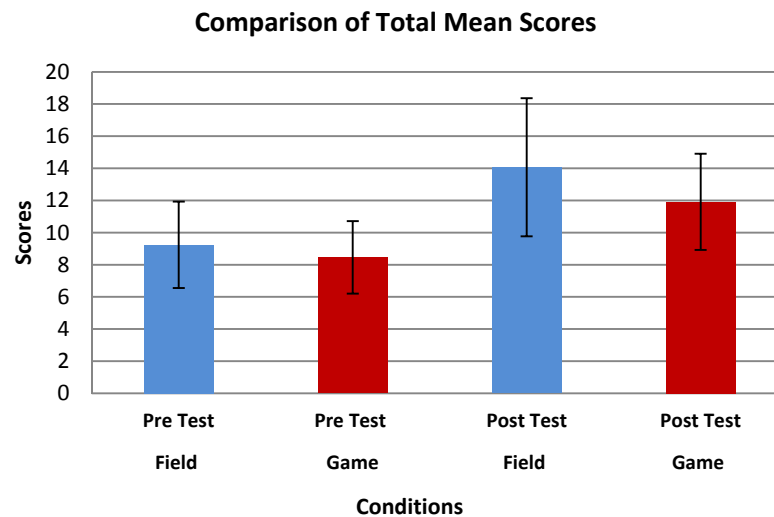


Figure 5.6 - Comparison of combined pre-post total test scores between Field and Game conditions

Fig. 5.6 shows a comparison of total mean scores both prior to the activity and after the activity for each condition. The descriptive results show that there was an increase in acquired knowledge for both conditions of the study.

### 5.8.1.1 t-test Results

A t-test was chosen as the analysis method as the group sizes were small and uneven (12 = Game, 23 Field). The t-test showed the groups were homogenous so equal variances were assumed.

Firstly, a paired-samples t-test was conducted for each group (Field and Game) to evaluate the impact of the activity on knowledge acquisition scores between pre and post-test levels.

- **Field**

The test revealed that there was a highly statistically significant difference between pre and post scores  $t(22) = -6.123$ ,  $p < .01$  (computed  $p = 0.0005$ ). The mean knowledge acquisition of post ( $M = 14.065$ ,  $SD = 4.3046$ ) was higher than the mean knowledge acquisition of pre ( $M = 9.239$ ,  $SD = 2.6920$ ). The effect size,  $d$ , was computed to be 1.38, which is a large effect size.

- **Game**

The test revealed that there was also a highly statistically significant difference between pre and post scores  $t(11) = -3.314$ ,  $p < .01$  (computed  $p = 0.007$ ). The mean knowledge acquisition of post ( $M = 11.917$ ,  $SD = 2.9911$ ) was higher than the mean knowledge acquisition of pre ( $M = 8.458$ ,  $SD = 2.2609$ ). The effect size,  $d$ , was computed to be 1.32, which is a large effect size.

Secondly an independent-samples t-test was conducted to compare the learning gain deltas for Field and Game. Table 5.2 shows the mean learning gain from each learning environment. The mean learning gain was derived through the normalised delta score of gain for each participant. The mean average of the field-trip learning gain was higher with a 10% increase, while the learning gain from the computer game experienced averaged a 7% increase.

Table 5.2 - Mean knowledge acquisition for both learning environment conditions

	Learning environment	N	Mean	Std. Deviation	Std. Error Mean
<b>Gains</b>	Field-trip	23	.100749	.0806080	.0168079
	Computer Game	12	.069639	.0716350	.0206793

The t-test revealed that there was no statistically significant difference between the learning environments of computer game and field-trip in regard to knowledge acquisition with  $t(33) = 1.124$ ,  $p > .05$  (computed  $p = .612$ ). The effect size,  $d$ , was computed to be 0.41, which is a medium effect size.

### 5.8.1.2 Knowledge Acquisition Summary

- The Field experience's pre-test scores marginally averaged above the game's by a difference of 0.78 points
- Results of the paired-samples t-test show that both Field and Game showed a highly significant difference between pre and post-test score levels.
- Results of the independent-samples t-test on the normalised scores show that no statistically significant difference was detected between the mean delta scores from the two learning experiences.
- As there is no significant difference between knowledge acquisition levels it shows that the Game condition was as effective as a learning environment as the Field condition

## 5.8.2 Perception on Flow Conditions

### 5.8.2.1 Descriptive Results

An initial analysis of the descriptive statistics for participant enjoyment on Flow conditions show that for the Field condition, 5 out the 8 categories measured proved to have a positive response of 50% or more. But the Game environment has a higher positive response to the Flow conditions of 70% or more in 6 out the 8 categories. The largest difference between the Field and Game groups were in the categories of Challenge where the Field gave positive responses of just over 40% but the Game gave positive responses of just over 90%. So it seems the Game was more positively challenging than the field experience. But when we look at social interaction, the trend is reversed with the Field experience having just under 80% of positive responses in comparison to the Game experience with under 40%. The data also shows that both groups had a similar positive response to perceptions of Goal Clarity and Concentration during the activities of the different conditions. It is also clear that Feedback, Immersion and Enjoyment were perceived to be more strongly positive in nature for the game than the field experience. This data is displayed in Figure 5.7.

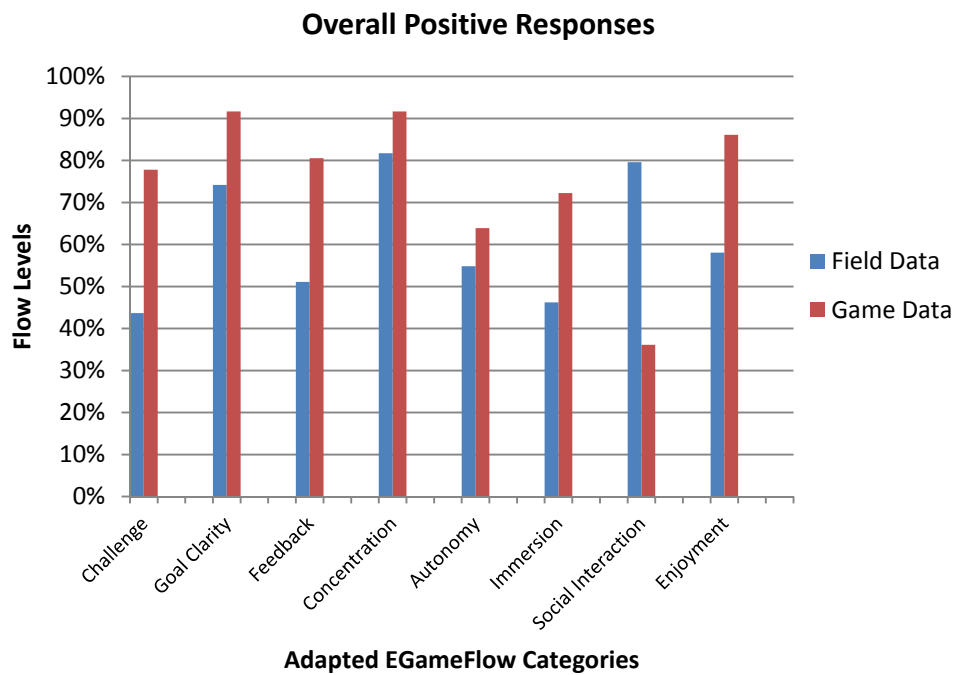


Figure 5.7 - Overall positive responses between the Field and Game experience

A Mann-Whitney U (MWU) test was carried out between the computer-game and field-trip on the EGameFlow criteria for participant enjoyment. This non-parametric test was chosen because as we had ordinal data from our 5 point Likert scale. A MWU is a non-parametric alternative to the t-test and matches our small and uneven group sizes. Firstly the 24 individual question scores were averaged into the 8 headline categories and analysed for difference. The trends in the mean rank per category between the field and game experience can be seen in Table 5.3.

Table 5.3 - The mean rank on participant enjoyment between Field and Game

	Groups	N	Mean Rank	Sum of Ranks
Challenge	Field	31	18.50	573.50
Delta	<b>Game</b>	12	<b>31.04</b>	372.50
Goal Clarity	Field	32	20.84	667.00
Delta	<b>Game</b>	12	<b>26.92</b>	323.00
Feedback	Field	31	19.73	611.50
Delta	<b>Game</b>	12	<b>27.88</b>	334.50
Concentration	Field	32	20.63	660.00
Delta	<b>Game</b>	12	<b>27.50</b>	330.00
Autonomy	Field	32	21.91	701.00
Delta	<b>Game</b>	12	<b>24.08</b>	289.00
Immersion	Field	32	19.77	632.50
Delta	<b>Game</b>	12	<b>29.79</b>	357.50
Social	<b>Field</b>	32	<b>24.33</b>	778.50
Interaction	Game	10	12.45	124.50
Delta				
Enjoyment	Field	32	20.53	657.00
Delta	<b>Game</b>	12	<b>27.75</b>	333.00

A higher mean rank score displays a positive trend towards higher participant perception based on Flow conditions. The trends in the descriptive mean data show that in terms of participant perception of the experience, the computer game was favoured in all categories with the exception of social interaction.

#### 5.8.2.2 Statistical Analysis Results

The MWU test results for statistical significance difference are shown in Table 5.4. In the categories of Challenge and Immersion a statistically significant difference was found. The mean rank of computer game simulation was higher than the mean rank of field-trip and so the computer game simulation had higher levels of Flow for participant perception on challenge and Immersion than did field-trip. This was also the case for Social Interaction where a highly statistically significant difference was found. But in this case the mean rank of computer game simulation is lower than the mean rank of field-trip and so the computer-game had lower levels of Flow for participant perception on social interaction than did field-trip.

Table 5.4 - MWU Results of Flow outcomes per category

<b>1. Challenge</b>	
<b>High statistically significant difference</b>	<b>U = 77.5, p &lt; .005 (computed p = 0.003).</b>
<b>2. Goal Clarity</b>	
No statistically significant difference	U = 139.0, p > .05 (computed p = 0.144)
<b>3. Feedback</b>	
No statistically significant difference	U = 115.5, p > .05 (computed p = 0.052) <b>Just outside of significance</b>
<b>4. Concentration</b>	
No statistically significant difference	U = 132.0, p > .05 (computed p = 0.103)
<b>5. Autonomy</b>	
No statistically significant difference	U = 173.0, p > .05. (computed p = 0.609)
<b>6. Immersion</b>	
<b>Statistically significant difference</b>	<b>U = 104.5, p &lt; .025 (computed p = 0.02).</b>
<b>7. Social Interaction</b>	
<b>High statistically significant difference</b>	<b>U = 69.5, p &lt; .01 (computed p = 0.006).</b>
<b>8. Enjoyment</b>	
No statistically significant difference	U = 129.00, p > .05 (computed p = 0.085) trend towards significance

Table 5.5 displays the MWU test results for the significant categories by their individual question. By looking at the result in this way we begin to get a feel for the nature of the differences between the two groups. For Challenge the primary difference was found in Question 1, where the participant perceived that the game allowed the difficulty of the challenges to increase as skills improved. For immersion it was also question 1, where those playing the game were able to ‘forget about time passing while involved in the tasks’ of the activity. But the field experience however, was perceived to have provided a more social environment where information could be discussed and shared.

Table 5.5 - Results of the statistically significant Flow category by individual question

<b>1. Challenge Category</b>	
Q1 - During the [activity] the difficulty of the challenges increased as my skills improved.	<b>Reject the Null Hypothesis</b> U = 102.5, $p < .025$ (computed $p = 0.022$ ) Mean rank of Game is higher than Field
Q2 - The [activity] provided new challenges with appropriate pacing.	Retain the Null Hypothesis U = 126.5, $p > .05$ (computed $p = 0.074$ , which is a <b>trend towards significance</b> ) Mean rank of Game is higher than Field
Q3 - The [activity] provided different levels of challenge that tailored to my ability	Retain the Null Hypothesis U = 117, $p > .05$ (computed $p = 0.059$ , which is <b>just outside of significance</b> ) Mean rank of Game is higher than Field
<b>6. Immersion Time</b>	
Q1 - I forget about time passing while involved in the [tools-based] tasks.	<b>Reject the Null Hypothesis</b> U = 96.5, $p < .01$ (computed $p = 0.006$ ), which is a <b>highly statistically significant</b> difference Mean rank of Game is higher than Field
Q2 - I temporarily forget any worries about everyday life while involved in the [tools-based] tasks.	Retain the Null Hypothesis U = 160, $p > .05$ (computed $p = 0.359$ )
Q3 - I felt emotionally involved in the [tool-based] tasks.	Retain the Null Hypothesis U = 138.0, $p > .05$ (computed $p = 0.134$ )
<b>7. Social Interaction</b>	
Q1 - I felt cooperative toward the other students [who were playing the video game next to me]	<b>Reject the Null Hypothesis</b> U = 100, $p < .05$ (computed $p = 0.045$ ) The mean rank of Field is lower than Game
Q2 - I strongly collaborated with the other students [who were playing the video game next to me]	<b>Reject the Null Hypothesis</b> U = 77.5, $p < .025$ (computed $p = 0.024$ ) The mean rank of Field is lower than Game
Q3 - The cooperation I experienced overall during the [tools-based activity] was helpful to my learning	<b>Reject the Null Hypothesis</b> U = 103.00, $p < .05$ (computed $p = 0.049$ ) The mean rank of Field is lower than Game

Finally in Table 5.6 display the significant individual questions of the remaining non-significant flow categories. These were in Feedback, Autonomy and Enjoyment who all had a higher mean rank for the Game condition.

Table 5.6 - Results of other statistically significant individual Flow question by category

<b>3. Feedback</b>	
Q3 - During the [activity], I received immediate information on my success (or failure) of the tool usage goals.	<b>Reject the Null Hypothesis</b> U = 98, $p < .025$ (computed $p = 0.012$ ) Mean rank of Game is higher than Field
<b>5. Autonomy</b>	
Q1 - I felt a personal sense of control and impact during the [activity].	<b>Reject the Null Hypothesis</b> U = 85, $p < .005$ (computed $p = 0.003$ which is a <b>highly statistically significant difference</b> ) Mean rank of Game is higher than Field
<b>8. Enjoyment</b>	
Q1 - I felt a sense of enjoyment whilst undertaking the [tools-based activity].	<b>Reject the Null Hypothesis</b> U = 121.5, $p < .05$ (computed $p = 0.041$ ) Mean rank of Game is higher than Field

### 5.8.2.3 Flow Conditions Summary

- Descriptive trends show participants who played the game left with a more positive perception of the experience than the field participants. For the game, the majority of EGameFlow categories scored over 70% positive as opposed to the field where just over half of the categories recorded a 50% positive perception.
- Analysis of the mean ranked scores show the game experience generated more positive perceptions on the EGameFlow categories, except for Social Interaction which was much higher in the field.
- The Mann-Whitney U test showed that three categories had a statistical significant difference between the two groups. These were in Challenge and Immersion with the game having a higher mean rank, and in Social Interaction with the field having a higher mean rank.
- In the remaining five categories there was not statistically significantly difference between conditions, although the categories of Feedback, Autonomy and Enjoyment had one individual question where we could reject the Null Hypothesis and two overall that were just outside of significance.

### 5.8.3 Correlation Outcomes

An analysis was conducted to compare the relative strength of the correlation coefficients' between the two conditions of Field and Game. A Spearman's rank-order test was selected as it is more suitable for correlations run with combined continuous and ordinal data, such as we have in this study. The purpose



was to look for relationships between Knowledge, Flow conditions and/or enjoyment and social interaction. By comparing the two groups we can gain insight into relationships and how the different learning environments impact those relationships. Preliminary analyses were performed to ensure no violation of the assumptions of normality, linearity and homoscedasticity. The coefficient of determination was calculated to give an  $R^2$  value between the pairs of variables. This is displayed as percentage of Shared Variance. Shared variance is calculated as an additional measure of association because of the small sample size.

#### 5.8.3.1 Knowledge Acquisition

For Knowledge Acquisition there were three data points, the total learning gain calculated from the pre/post scores, the total pre-activity scores and the total post-activity scores. Results of the Spearman's rank-order test found a large positive correlation between total learning gain and Challenge for Field with a shared variance of 32% [ $r=.572$ ,  $n=22$ ,  $p<.005$ ]. For Game a similar large negative correlation was found between total learning gain and Autonomy (Control) with a shared variance of 35% [ $r=-.593$ ,  $n=12$ ,  $p<.042$ ]. However these were the only significant results found for both Field and Game on total learning gain. On the pre-activity scores no correlations were found with the Flow categories. For the total post-activity scores, the Field returned a medium positive association on Immersion but with only a 17% shared variance [ $r=.416$ ,  $n=23$ ,  $p<.048$ ]. For Game there was a medium negative association on Autonomy (Control) with shared variance at 22% [ $r=-.477$ ,  $n=12$ ,  $p<.117$ ]. No other correlations were found. The results show that there was limited evidence of association between knowledge acquisition and Flow conditions in this study.

#### 5.8.3.2 Flow Perceptions

Next we wanted to know if the two none Flow categories of Social Interaction and Enjoyment has a positive correlation with the six Flow categories. Table 5.7 displays a matrix of the significant results and their calculated shared variance. The results are shown for the two groups with the shaded cells indicating significance and/or shared variance of 30% or above. Where a significant value was found in one group but not the other the non-significant results are displayed alongside. Blank sections mean no significance or low shared variance found in either group.

When we look for correlation between Social interaction and the conditions of Flow. We see a moderate effect for Challenge in the Field condition, at 27% shared variance, compared to the weaker association shown for Game. A larger difference is shown for Concentration with the Game at 37% compared to the Field at just 3.3% shared variance. The two largest correlations occur between perception of Social

Interaction and positive perceptions on Immersion with shared variance for Field at 37% and Game at 60%.

When looking for high levels of shared variance between Enjoyment and Flow conditions the Game treatment displays levels above 30% for Challenge (31%), Feedback (50%) and Immersion (52%) whereas the Field treatment only displays an association with Autonomy (30%). For the categories of Goal Clarity and Concentration no correlation was found for either Field or Game.

Table 5.7 - Spearman's rank-order correlations between Flow Conditions Social Interaction and Enjoyment

Measures	Social Interaction		Enjoyment	
	Field	Game	Field	Game
<b>Challenge</b>	.523** Sv27%	.424 Sv 17%	.269 Sv7.2%	.565 <b>Sv31%</b>
<b>Goal Clarity</b>				
<b>Feedback</b>			.086 Sv0.7%	.712** <b>Sv50%</b>
<b>Concentration</b>	.183 Sv3.3%	.610 <b>Sv37%</b>		
<b>Autonomy (control)</b>			.548** <b>Sv30%</b>	.425 Sv18%
<b>Immersion</b>	.197 <b>Sv 37%</b>	.778** <b>Sv60%</b>	.441* Sv19%	.722** <b>Sv52%</b>

N=32 Field N=12 Game

\*. Correlation is significant at the 0.05 level (2-tailed).

\*\*. Correlation is significant at the 0.01 level (2-tailed).

sv = shared variance

In Table 5.8 we look at whether there are any correlations between Total Learning Gains and our two non-Flow conditions, Social Interaction and Enjoyment. It is clear that the strength of relationship is very small across both conditions of Field and Game. At its highest shared variance between variables only reaches a maximum of 5%.

Table 5.8 - Correlations between Social Interaction, Enjoyment and Learning Gain

Measures	Total Learning Gain	
	Field	Game
<b>Social Interaction</b>	.401 Sv16%	.078 Sv0.6%
<b>Enjoyment</b>	.225 a Sv5%	-.229 Sv5%

N=23 Field N=12 Game

\*. Correlation is significant at the 0.05 level (2-tailed).

\*\*. Correlation is significant at the 0.01 level (2-tailed).

sv = shared variance

In Table 5.9 we look for correlations between the variables of Enjoyment and Social Interaction. The strongest relationship is for Field but it is only a medium effect and the shared variance is only 21%. The game condition displays a very weak relationship with a shared variance of 0.7%.

Table 5.9 - Correlations between Enjoyment and Social Interaction

Measures	Enjoyment	
	Field	Game
<b>Social Interaction</b>	.467* Sv21%	.085 Sv0.7%

N=23 Field N=12 Game

\*. Correlation is significant at the 0.05 level (2-tailed).

\*\*. Correlation is significant at the 0.01 level (2-tailed).

sv = shared variance

The next step in analysing the results would have been to take the results from the two groups in the study and undertake an analysis to see if there is statistically significant difference between the sets of results. Unfortunately the groups sizes are too small for us to have enough power to gain any further insights.

### 5.8.3.3 In Summary

- The results show that there was limited evidence of association between knowledge acquisition and Flow conditions in this study. Although the Field condition shows a positive association with Challenge on total learning gains. For the Game there was a medium negative association between learning gains and Autonomy.

- Enjoyment had a strong relationship to the Conditions of Flow in the Game treatment. There was a strong relationship for Challenge, Feedback, and Immersion with a minimum shared variance of 31% and a maximum of 52%. The Field however only showed a relationship with Autonomy at 30%.
- For Social Interaction only the Field showed a strong correlation with Challenge (27%) and Immersion (37%). Whereas the Game showed strong association in Concentration (37%) and Immersion. With immersion having 60% shared variance.
- Outside of the conditions of Flow when learning gains were analysed with Enjoyment and Social Interaction the strength of the relationship is very small with a maximum shared variance of 5%
- There was a medium strength of relationship between social interaction and enjoyment in the Field condition but only a weak relationship for the Game.

## 5.9 Discussion

The aim of the study was to understand whether the gameplay design supports a student's ability to undertake skilled tasks and whether the design enables conditions for enjoyment known as optimal experience (Flow). We investigated this aim in two parts. Through assessment of the level of knowledge acquisition we would be able to establish if the game design supported our student's ability to undertake skilled tasks. Through assessment of the participant perception on Flow conditions in the form of the adapted EGameFlow questionnaire (Fu et al., 2009) we could assess the design for its ability to elicit the state of optimal experience. Analysis of these results in meeting the aim of the study will allow us to make inferences as to whether the Structural Playability Process (SPP), was proving to be an effective design approach that can support both skill learning and enjoyment.

### 5.9.1 Knowledge Acquisition

There were four research questions we were trying to answer in the study. The two questions related to establishing knowledge acquisition are:

1. Does playing an inquiry-based videogame, versus traditional methods (closer to lecturing, or fieldwork) have higher overall learning gains?
2. Does the gameplay design support a skilled performance?

The descriptive statistics of the Pre and Post skill-test scores show that participants for both Field and Game had an increase in subject knowledge after their experiences in the learning environments. But the post-test scores show that those who did the activity in the field slightly outpaced those who did the activity via the game.

Even though there were minor differences in the means of the knowledge gains between the field and the game, the independent samples t-test analysis found that these differences were not statistically significant. Therefore, the results show that it is possible to support hypothesis H5.1; that a computer game simulation of geothermal field activities designed using the Structural Playability Process (SSP) can support positive knowledge acquisition and reject  $H_0$  that the game environment failed to support positive knowledge acquisition.

In terms of answering the research questions, the game was designed to provide an increase in task difficulty and complexity within a self-directed space. The participants were allowed to undertake each task in the manner that suited them, they had: 1) no restrictions on where they could roam in the world; 2) what they could interact with; and 3) how much time they took. These freedoms allowed for a self-determined (Deci & Ryan, 1985) approach to the activities tasks. Although this enquiry-based approach to the activity did not generate higher overall learning gains, the gains between the groups were not significantly different either. Therefore, a game designed following the SPP approach provides a sound methodology for mapping learning outcomes into game strategies that achieve positive knowledge acquisition.

As for the more direct question of establishing whether the gameplay design supported a skilled performance? It is clear that as the game participants experienced positive learning gains. We argue that it was the SPP gameplay design that supported the skilled performance of the participants which was due the design approach of the SPP which structured the gameplay content as a series of goal related, skill based tasks that followed a logical structure for providing goal focused feedback and progression (Bradshaw, 2007).

### **5.9.2 Perceptions on Flow Conditions**

The intention when measuring perceptions on Flow conditions was to establish the level of involvement with the experience so we could assess the traditional field method of teaching to the SPP game designed method. This should allow us to infer what aspects of Flow are supported through the game design. The specific conditions of Flow tested through the questionnaire were Challenge, Goal Clarity, Feedback, Concentration, Autonomy (control), and Immersion. The remaining Flow categories of Enjoyment and Social Interaction will be discussed with the correlation outcomes in the following section. The research questions we are addressing with this measure are:

1. Does playing in a realistic/authentic computer game impact student attitudes in a positive way?

2. What is the difference in the level of enjoyment in the learning experience between traditional (tutor or lecturer-controlled and modeled) as opposed to inquiry-style gameplay (self-determined; control over decisions and path)

The descriptive trends (Fig. 5.7) and the mean ranked scores (Table 5.4) have shown that the game experience generated a more positive perception on Flow than the field experience. When submitted to statistical testing, we found a significant difference in the categories of Challenge and Immersion, with the Game participants experiencing a higher level of positive perception than the Field participants. Challenge and Immersion are the start and end points on Csikszentmihalyi's, (1990) eight stage path to an optimal experience. By dipping into the individual Flow questions of our post activity questionnaire we get an indication of what the most engaging aspects of the experience were.

On perceptions of Challenge, which is described in Flow as a challenging activity that requires skills, the largest difference was in positive perceptions that the difficulty of the challenges increased as skill improved. This was closely followed by positive perceptions that the activity provided different levels of challenge that tailored to user ability. Thirdly, (with the least difference) that the activity provided new challenges with appropriate pacing. The strength of the game's design is in its capacity to challenge the participants through matching difficulty to skill level. This balance of challenge and skill-level, paced through increased difficulty is a key part of both Flow (see section 3.1.2 Fig. 3.2) and Skilled Performance (section 2.3.1). The gameplay tasks were delivered via the mission system that deployed the SPP strategy for inducing a skilled performance. The intention was to provide increasing degrees of difficulty for each progressive task. Although the field activity followed the same pattern of tasks, (see Table 5.1) there was no intention with the field tasks to manage the difficulty pacing in a similar manner.

When considering Immersion, Sweetser & Wyeth, (2005) in their GameFlow evaluation model and Fu, et al., (2009) with the EGameFlow scale, combine these consequences of Flow; 'the loss of self-consciousness' and 'the transformation of time'. Out of the three questions asked it was question 1: *"I forget about time passing whilst involved in the task"*, that gave the category its significant difference. The other two questions asking about whether they forgot about everyday worries and felt emotionally involved in the tasks showed no indication of a difference between environments, although the game did generate more positive responses.

The significant differences between the Game and the Field for the start and end conditions of Flow indicates that the application of the SPP game design was successful at providing an environment where

conditions for entering a flow state would be present. Although unrelated variables such as the novelty of the gameplay experience could influence the outcomes.

To understand what was happening along the journey between challenge and immersion we can examine the significant differences from the individual questions of the non-significant categories. Feedback and Autonomy are of interest from the non-significant results (Table 5.5) as they trend toward significance. For Feedback, there was a significant difference on question 3 for positive delivery of feedback on goal success and failure. Question 2, asking about feedback on overall progression, fell just outside of significance. But there was less of a difference in perceptions on immediate task action feedback. On ‘Clear goals and feedback’ Csikszentmihalyi (1990) states that ‘feedback can be enjoyable, provided it is logically related to a goal in which one has invested psychic energy’. The underlying purpose of the SPP is its use of the skilled performance principles to provide the required logical linkage of tasks to goals (section 3.2).

For Autonomy, which measures the sixth condition of Flow, the paradox of control, question 1 showed a highly significant difference, measuring positive values on feeling a personal sense of control and impact during the activity. Users also felt more positively towards being able to anticipate what the next steps would be in the activity. However, there was less difference between groups when asked about their sense of control over the tasks they were asked to do. In both treatments of the study the participants had no control over what tasks they were asked to do. In the Game condition each task was dependant on the completion of the previous task for progression, whereas the field experience was more adaptable due to the human teaching element. But in spite of this it seems that the game experience provided a stronger feeling of control. This matches what Csikszentmihalyi (1990) says of the paradox of control in that it is ‘the possibility, rather than the actuality, of control’ to which our participants were responding. Analysis of the metric data will allow us to see what actions those who experience feeling a high level of control were doing within the game environment.

The remaining categories where there was no statistical difference between the groups were in the Flow conditions of Clear Goals and Concentration on the Task at Hand. Both of the two treatments in the study experience 70% or more positive perceptions so both learning experience gave clear goals and enabled concentration.

So in light of the positive perceptions on conditions of flow that the game induced over the field experience it is possible to support H5.2: That a computer game simulation of geothermal field activities

designed using the Structural Playability Process provides an learning environment that better promotes conditions for a state of optimal experience, otherwise known as 'Flow', when assessed against a baseline from the traditional and proven method of a real-world field-based activity and reject the null hypothesis.

Turning back to our research questions the findings of this study show that playing in a realistic/authentic computer game does impact student's attitudes in a positive way, even more so than the traditional field experience. Our findings indicate that involvement was stronger when the tasks were undertaken in the game environment rather than in the field. But it is unclear as to whether this was a consequence of the different learning approaches or as a result of unforeseen variables at play. In the next section discuss the relationships between the Flow conditions and the other factors under measure.

### 5.9.3 Correlation Outcomes

No evidence from the correlation outcomes of this study was found to support a direct link between knowledge acquisition and a Flow state. Other similar studies (Kiili, 2010; Rossin, Ro, & Klein, 2009) also could not provide direct evidence to establish a link. This does not mean that a link doesn't exist as Rossin et al. state 'support is found for a relationship between flow and students' perceived learning of the subject matter'.

There was also no correlating relationship to be found between Total Learning Gain and Social Interaction and Enjoyment. Although there was a higher level of shared variance between the Field learning gain and positive perceptions of Social Interaction (16%). This could indicate that some degree of socialness can improve knowledge acquisition.

The correlation trends show that the Game experience showed a stronger relationship between the Flow conditions and enjoyment than the Field. It was found that the categories which showed a significant difference on perceptions on Flow conditions in the game (Table 5.4) were also the categories that had the strongest correlation results with Enjoyment. With the highest shared variance seen in Immersion (52%), Feedback (50%) and Challenge (31%). These high levels of shared variance are a positive indicator that the design was able to support the enjoyable experience that constitutes a feeling of Flow. Csikszentmihalyi, p49 (1990) states '*the combination of all these elements causes a sense of deep enjoyment*' so we should be seeing these kinds of trends if we are correctly designing for an optimal experience. As a cautionary note from the perspective of this study, the design was intended as



the impacting variable on these correlations but that does not mean we have established clear cause and effect as other unplanned factors in the environments could also be having an impact.

In terms of social interaction it appears that the stronger associations with the Flow conditions were found in the Game experience. This is interesting as the trends (Fig 5.7) and Mann Whitney U results (Tables 5.3 & 5.4) showed the Field to have the higher positive perceptions of social interactions over the Game. In light of this we can offer no indication of why these relationships have occurred. If anything it would be more likely that the game would show a negative correlation to social interaction as the game was single player and therefore not social in its nature. Further investigation with a larger sample size may shed light on these results.

Finally, when looking for relationships between Enjoyment and social interaction (Table 5.9) as expected no relationship was found for the Game condition (0.7%) as the gameplay was single player. Although, the Field condition did show some level of shared variance between enjoyment and socialness (21%), which reflects the more social nature of the field-trip experience.

### **5.10 Conclusions**

The GeoThermal World computer game provided an effective alternative to a real-world geothermal field-trip. The game was able to support learning that was comparable to the established field-trip method of teaching. The statistical tests found no difference in learning gains between the established tutor-led teaching of a real-world field-trip, and the self-determined learning of the game world.

The Structural Playability Process (SPP) method of applying learning outcomes into a gameplay missions was effective for exploring geothermal resources via a free roaming authentic computer game environment. In addition to this the SPP designed computer game was better able to generate the conditions of Flow, especially in the areas of Challenge and Immersion, when compared to the field-trip experience.

We also found that enjoyment and Flow conditions shared a relatively strong relationship in the Game condition over the Field. This supports Csikszentmihalyi's (1990) findings that Flow and the feeling of enjoyment are indeed linked. We conclude that it can be inferred that application of Skilled Performance theories (Fitts & Posner, 1967) as a scaffold, within the SPP gameplay design, had a positive impact on the players ability to experience an enjoyable, Flow inducing activity.

In this study, as was the case with other studies (Kiili, 2010; Rossin et al., 2009) we did not find any relationship between the level of learning gain and Flow, Enjoyment or Social interaction.

In answer to Development question 3 – “Will the games when complete meet the learning outcomes of the client through providing the Target Audience with an engaging gameplay experience that provides subject knowledge?”. We conclude that the outcomes of this study do indeed provide support that an SPP designed game can provide engaging gameplay that improves subject knowledge.

### **5.11 Lessons Learned**

There was a missed opportunity to establish the long-term knowledge retention outcomes between the two different environments. A consideration for further studies would be to have all skills tests and Flow questionnaires accessible online, where we could reach participants at their convenience regardless of passage of time or geographical location.

Due to the difficulties in building a whole game world from scratch we created an inequality between groups as the final learning task in the game went unapplied. It was difficult to establish if this impacted the level of knowledge acquisition between the groups. Recommendations for future user studies for testing the SPP process will take this into consideration. Therefore we recommend that the next experimental study should be careful to provide the participants with the same set of skill-based tasks.

In this study there were uncontrolled for variables introduced by the large differences between the two learning environments e.g. a real-world Field-trip and a virtual Game. To have more certainty that the resulting outcomes were indeed induced by the SPP design process; and not influenced by outside factors, it would be wise to control the experimental conditions of the next study. By more closely matching the conditions experienced by the participants, in the two learning environments, we would be better able to infer that any differences found were due to the application of the SPP design rather than other factors.

### **5.12 Further development and testing of the SPP**

The next two chapters present the design, development and experimental outcomes the other SPP designed game; *“Ora – Save the Forest”*!

The following chapter will outline how the design approach of the SPP’s four developmental ‘Spaces’ structured the learning outcomes and gameplay. The subsequent user study chapter will address the lessons learnt from in this study, by introducing an additional measure for assessing knowledge retention, guidelines for ensuring both experimental conditions offer the same set of skill-based learning tasks, and a refinement of the experimental conditions of the comparative learning environments to reduce confounding variables.

# 6

## Ora – Save the Forest! Design Implementation

This chapter outline the steps taken in the design implementation of the Ora game. It attempts to illustrate the process that was undertaken by the designer in order to address the following development questions as laid out in the research strategy section of chapter 3:

1. Can the SPP be followed as a design approach when presented with a real-world client problem?
2. Can the designer implement the learning outcome and objectives of the client into a gameplay system that can be built in a game engine?

The Ora game is part of a research programme aimed at increasing community participation in pest management decision-making. This project was in collaboration with Landcare Research, one of eight Crown Research Institutes (CRIs) accountable to the New Zealand Government and located in Lincoln, New Zealand.

By following the SPP approach to game design we mapped out the core parameters of the design for the Ora gameplay. The clients complex problem was that ‘the public should gain a realistic appreciation that management of this (or any) ecosystem is a complex problem’. This led to a shared intrinsic motivation between the client and target audience of ‘maintaining and restoring the eco-system of NZ forests based on biodiversity conservation’. With the shared extrinsic motivation of reducing Possum numbers. On the client side, in representing eco-science we have a separate extrinsic motivation of being able to control possum numbers both temporally and spatially and to promote understanding. The public specific extrinsic motivations were found to be rooted in bird and tree recovery with a continued buy-in to the 100% pure New Zealand ethic while keeping continued support for game species, such as non-native deer.

Understanding the problem in these terms formed our learning outcome. Through engagement with the game the player should to gain a realistic appreciation that management of an ecosystem is a complex problem. This would be reached through the learning objective of maintaining and restoring the eco system of NZ forests based on biodiversity conservation.

To support this learning outcome a simple narrative was constructed, in which the public is the hero saving the fragile, beautiful, but resilient eco system from the jaws of the invasive Bushtail Possum. This narrative provided the context for the primary game goals: To repel an army of mammalian pests led by marauding possums, save the native flora and fauna and restore the forest ecosystem to its former glory. For the purposes of this research we focused on developing the initial level of the game. Within the context of the narrative we developed a goal for this level where the player was tasked with the creation of an area of forest suitable for a kiwi sanctuary; an area that has low to no Possum numbers.

Once the level goal was established, we focused on breaking down the level outcomes into manageable Skill Stages. This chapter details Skill Stage 1, in which the player undertakes basic environmental monitoring. Their task is to monitor the flora to establish the health of the environment. The Skill Stages are then mapped directly into Mission Sets with Mission Set 1 of the gameplay titled Environmental Monitoring. Mission 1 of the Environmental Monitoring set has two gameplay missions; (1) identify the trees to protect and (2) find out how healthy they are. The chapter goes on to describe how Mission 1 - Protect and Preserve; Identify the tree to monitor, was implemented in the game engine.

In this chapter we present the design process of the game via the simplified linear form of the SPP approach, with reference to the SPD model where appropriate. We will address each design space in turn, and describe in detail the level, skill stage and mission design and how they related to each other. We begin with the overview of the full game via the Educational and Translation spaces, before providing specific detail of the level, gameplay and mission design in the Design and Engine spaces. Figure 6.1 once again provides a reminder of the SPP structure in line with the chapter content.

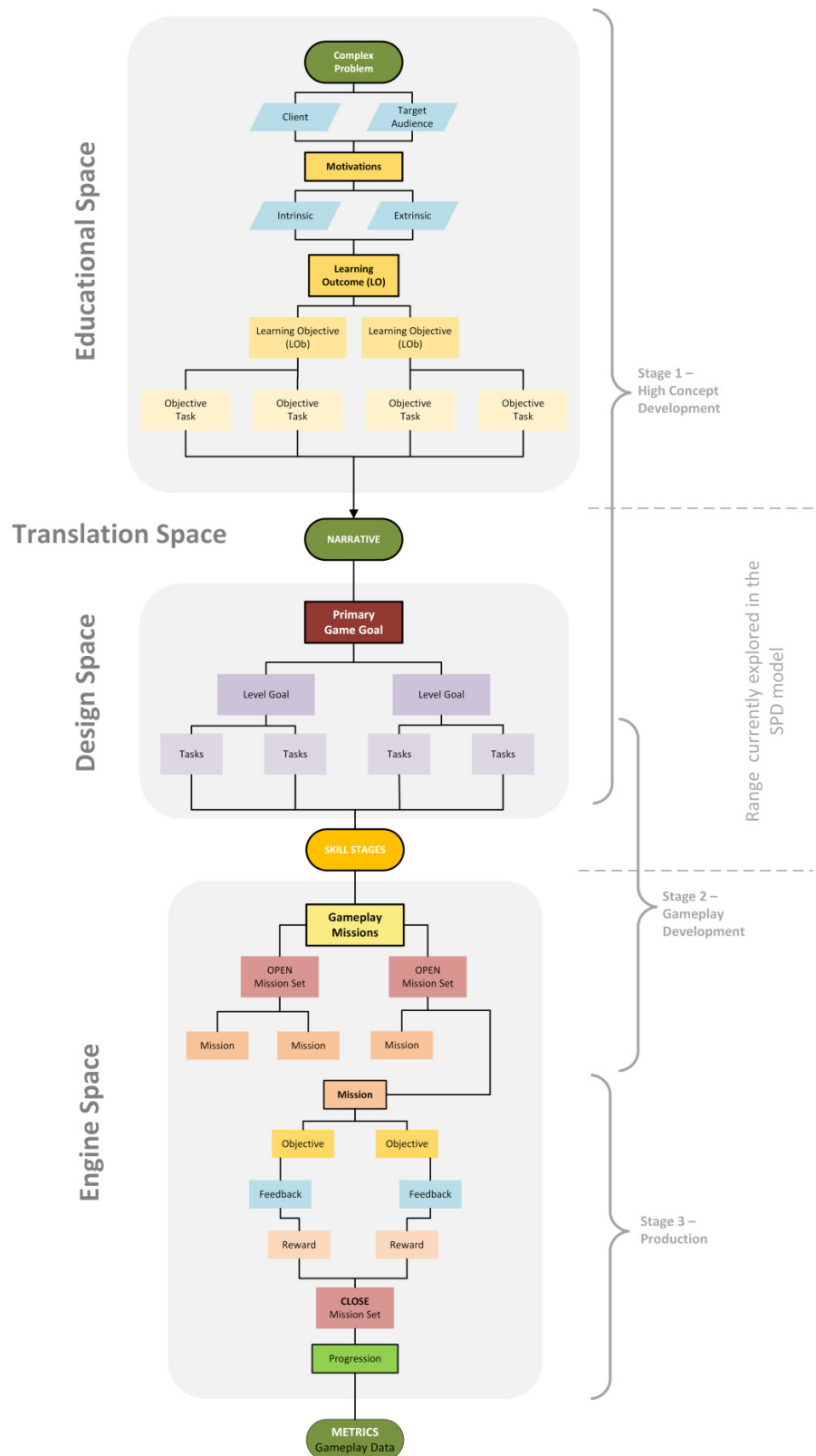


Figure 6.1 – The full SPP structure

### 6.1 Educational Space

The Educational Space of the SPP drives the game design by linking a complex problem to the gameplay narrative. Ora-Save the Forest! is a pest management game. Its purpose is to engage the public with the management and control of Possums in New Zealand's native forests. Dr Penelope Holland, a scientist and ecological modeller, designed and developed a mathematical simulation model (SM) of pest management interactions, which underpins Ora's gameplay. Dr Holland engaged with this doctoral research as a way to place this complex scientific simulation in a form that could be easily used by non-specialists. The implementation of this model into a gameplay form provides the player with real-world, accurate scientific interactions and reactions, with the science, when playing for fun. The model was further developed into the Possum Sim Science GUI (PSSG) where the simulation was adapted for integration into the Unity3D game engine.

### 6.1.1 Identifying the Complex Problem

Pest control in New Zealand is a contentious issue: scientific research indicating the consequences of management (or lack of it) is not well known, understood, or accepted by some members of the general public who have a stake in the process (e.g. land owners and managers, recreational land users). These people need to be engaged with the process in order to make informed decisions about pest management on their land or in their communities. Academic papers are difficult to access and understand for the layperson, and

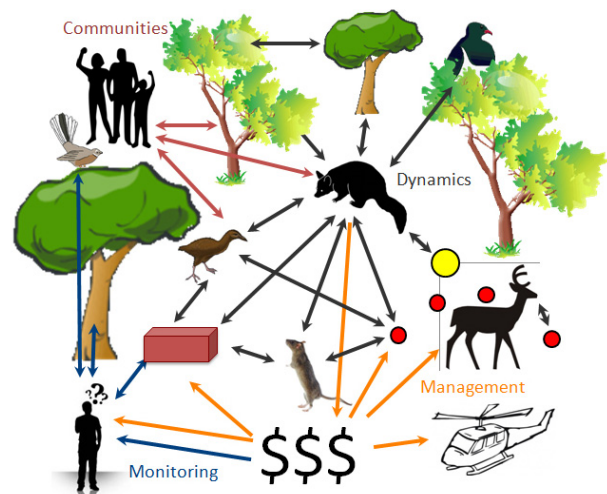


Figure 6.2 - Complex interactions of pest control for biodiversity in New Zealand

most scientific knowledge transfer to date has been via media releases, or through workshops or word of mouth. However it is difficult to get a national scale audience engaged through these routes. Developing a game based on pest management research is a novel way to engage and inform the general public directly with up to date science, and to help players gain a realistic appreciation that management of an ecosystem is a complex problem (Fig.6.2).

## 6.2 Defining the Purpose: Client and Target Audience

The project client was Landcare Research. They represent the collective set of stakeholders who wish to bring the science of pest management control to the general public, the target audience (TA). We applied the term ‘Scientists’ for our client descriptor as it more accurately covers the multiple

stakeholders involved. We developed a project rationale to guide the development of the game and its outcomes. It consists of four parts; (1) an aid to public dialogue and engagement with a complex problem; (2) scientific knowledge transfer; (3) the use of novel media to present environmental information, and; (4) innovative and engaging ways to implement and present research findings. This provided us with an agreed starting point for defining 'client' motivations. Our target audience covered a broad range of people and, in consultation with Landcares' researchers, we identified the types and groups that we would need to engage. The core demographic of the general public that we most wanted to engage were rural New Zealanders, both male and female, aged 40+, with a tertiary education but who were not necessarily academics.

### **6.2.1 The Motivations**

Understanding what motivates both client and audience establishes the learning outcome, learning objectives and objective tasks. Results of the research consultation established, both scientific motivators (client), and public motivators (TA). Public and scientific drivers on this topic are exactly the same. Both groups are intrinsically motivated to conserve and restore the natural eco-system. This creates a gameplay framework based on common ground with acceptable twin purposes. Where the motivators diverge and become externally driven is through the route and course of action that each stakeholder prefers to take. Figure 6.3 illustrates the shared intrinsic motivation between scientist and public, and then the subsequent extrinsic motivators. It is in the extrinsic motivators where we found a different perspective on the problem.

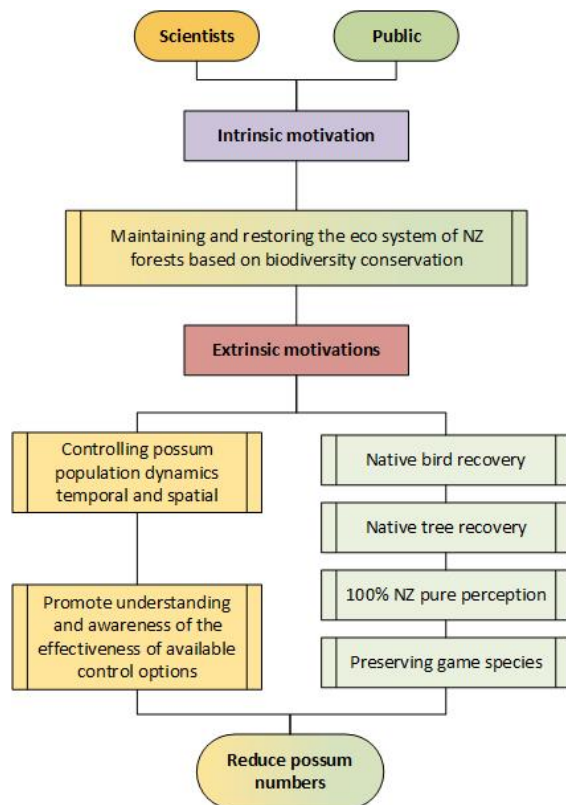


Figure 6.3 - Structure of motivations between Client (left) and Target Audience (right)

*Intrinsic* motivations are internally driven, where an activity is undertaken for its own sake rather than working towards an external reward; for example, wanting to achieve the aspirational goal of maintaining and restoring the New Zealand forest ecosystem and biodiversity. This intrinsic motivation is shared between client and target audience.

*Extrinsic* motivations are externally driven and can be attributed to the influence of external factors; for example, wanting to see native bird recovery as a consequence of maintaining and restoring the forest ecosystem. The client-centred extrinsic motivations are concerned with controlling possum population dynamics, temporally and spatially, with the aim of promoting

understanding and awareness of the effectiveness of available possum control options. The game should therefore allow players to interact with the underlying science to experience this. The extrinsic motivators of the target audience are to see native bird and tree recovery, game species preservation and maintaining a 100% NZ pure perception. Therefore, the game-world, its narrative, and rewards should be able to support these motivators.

The gameplay needs to allow the public to experience an equal sense of involvement in the problem-solving, enabling public perception of involvement to be closer to that of the 'scientist'. This sets the groundwork for a system of reward and feedback opportunities that enable the public and scientist to perceive the value of each other's input. In terms of gameplay, the common ground on which we focus this perception change is the non-native Possum. Therefore, making the Possum the foundation of the gameplay from which all other aspects of management of a New Zealand eco-system can grow.

## 6.2.2 Learning Outcome and Objectives

The learning outcome provides the educational design directive for player achievement. Learning outcomes 'articulate the relationship between what [educators] teach and what students do, in fact, learn' (Allan, 1996). Learning outcomes and objectives ultimately define the primary game goals in the



correct context. It describes the scope of the activity of the player. Considering the motivations of client and target audience in the context of the complex problem allowed definition of the learning outcome and objectives for Ora. The learning outcome was formed by considering the complex problem of pest management, within the Landcare Research aim of increasing community participation.

Therefore, after engaging with the Ora computer game the participants would be able:

**Learning Outcome** - To gain a realistic appreciation that management of an ecosystem is a complex problem.

Through the:

**Learning Objective:** Maintaining and restoring the eco system of NZ forests based on biodiversity conservation.

The learning objective is taken directly from the shared intrinsic motivation. The extrinsic motivations describe the framework on which the objective tasks are guided. The scientific extrinsic motivations of; (1) controlling possum population dynamics temporal and spatial; and (2) promote understanding and awareness of the effectiveness of available control options, is a guiding framework for gameplay actions. The public's extrinsic motivations describe the outcomes that our TA would like to experience from the gameplay.

Player's achieve the learning outcome via the application of learning objectives, which are broken-down into Objective Tasks. These tasks have their own levels of complexity that increase with difficulty as the player/learner progresses.

These Objective Tasks guide the development of the gameplay levels. In the first iteration the Objective Tasks guiding the gameplay design are:

1. Monitor Environment
  - i. Assess tree health
  - ii. Assess possum impacts
2. Manage Environment
  - i. Keep trees healthy
    1. Reduce Possum impact
      - a. Deploy control methods
      - b. Assess control methods

We follow the steps of the Educational Space of the SPP approach in matching stakeholder motivations to the outcomes and objectives. We begin to support the Structural and Goal principle of the SPD model where skilled performance always involves an organised sequence of activities, and skilled behaviour is goal directed. At this point in the design process we are within, Stage 1 - High Concept Development, of the SPD model where the narrative elements are assessed against the the Structural and goal principles (see section 2.4)

### **6.3 Translation Space**

The purpose of the translation space is where the motivations, learning objectives and objective tasks are embedded within a simple narrative, contextualising the gameplay for the player and the designer who aims to ‘maximize the player experience through the planning, structure and execution of the key elements of Gameplay Progression (mechanics, duration, ancillary rewards, practical rewards and difficulty)’ (Lopez, 2014).

#### **6.3.1 Narrative overview**

We build the game premise around our simple narrative, that:

***The public is the hero saving the fragile, beautiful but resilient eco system from the jaws of the invasive Bushtail Possum.***

Our game narrative takes place within a present day native New Zealand forest, such as the rain forest found on the West Coast of the South Island. The forest contains native trees such as Kamahi, Rata and Totara. It also contains the invasive Bushtail Possum, introduced from Australia 150 years ago by settlers eager to establish a fur trade. There are 30 million Possum eating their way through defenceless native forest and birdlife. On average they cost \$60 million a year to control and occupy 95% of New Zealand.

#### **6.3.2 Plot Scenario**

In the game the player is introduced to the game world through an omnipresent entity, Tāne Mahuta; the Māori God of the forest (Miller, 2003 pvi). Tāne holds guardianship of the forest, attempting to balance the forest eco-system so it can return to its former glory. In the game Tāne Mahuta is the embodiment of the Learning Objective: maintaining and restoring the eco system of NZ forests based on biodiversity conservation. Ora is set in modern day so our entity not only has to balance the eco-system it also has to deal with modern day challenges such as budget controls, ethical dilemmas and meeting the needs of conflicting groups of concerned citizens. It is Tāne who enlists the help of the player to save the forest. In the centre of the forest is a giant tree. This tree is the physical embodiment of our forest

God. Inside this tree, known as the control tree, is the research centre. The research centre setting is the gameplay interface that the player uses to monitor, interact and control the underlying simulation model of pest management interactions. It is here that we find Liana a non-player character (NPC). She is the player's main point of contact inside the game world. In the narrative Liana's role is a research scientist who acts as liaison between Tāne, game-world and player.

## **6.4 Design Space**

To fulfil the narrative premise of our hero saving the forest from possums we devised the set of primary game goals to lead the gameplay design. These goals guide the gameplay and level development. It is from these game goals that we breakdown the skill based tasks to be clustered into skill stages.

The simulation model that underlies the Ora game provides the player with the framework and methods for achieving the gameplay goals. The framework integrates models of possum dynamics (birth, death and movement) (Ramsey & Efford, 2010), possum impacts on tree canopy health and mortality (Holland et al., 2013), possum interactions with management tools such as traps (Ball, Ramsey, Nugent, Warburton, & Efford, 2005) and poison bait (Tompkins & Ramsey, 2007), and cost (time and money) for executing environmental monitoring or management. The simulation model allows players to set up "operations" comprising a series of actions, such as choosing contractors, transport and equipment, setting trap or bait station layout, and then providing quotes and implementing operations at the appropriate time. It thus provides the basis on which to build gameplay. The simulation model has been wrapped in a graphical user interface (GUI) for scenario playing by managers (the "Possum Sim Science GUI," or PSSG,). Figure 6.4 shows a screenshot of the Possum Sim Science GUI (PSSG) that forms the basis of the Ora gameplay.

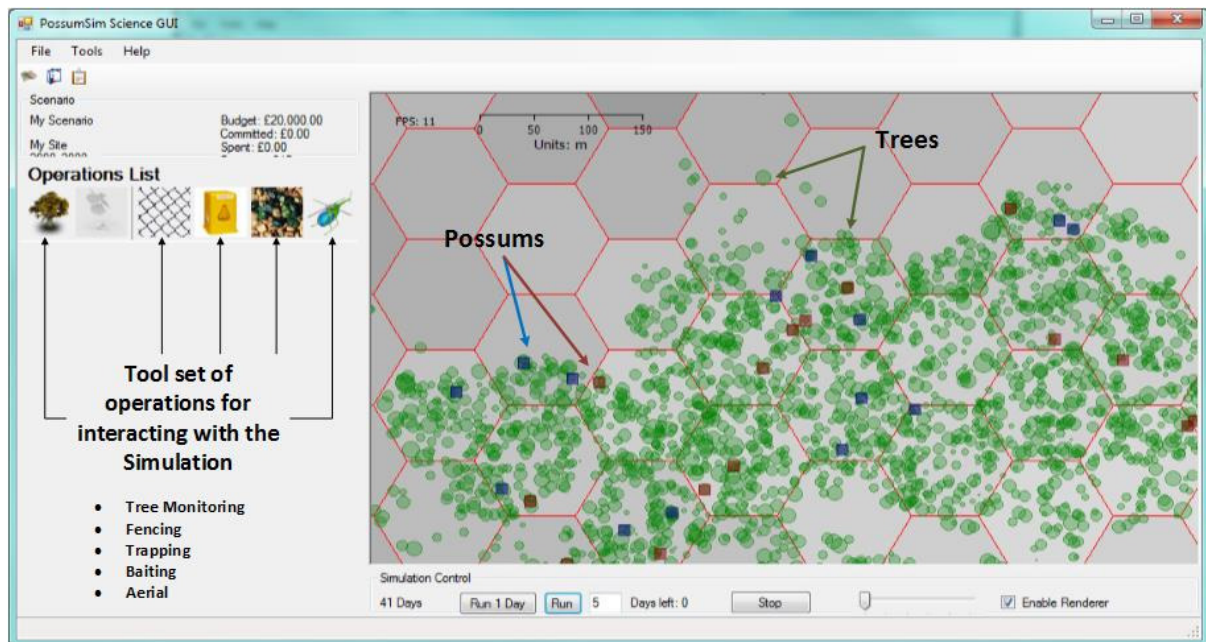


Figure 6.4 - A screenshot of the Possum Sim Science GUI (PSSG) that formed the basis of the Ora gameplay

### 6.4.1 Primary Game goals

The primary game goals frame the objective of the gameplay. They are a result of the translation of learning outcomes and objectives filtered in narrative context. They reflect player the motivations and form the basis of the narrative progression. In Table 6.1 the primary game goals are listed on the left. These goals are derived from the learning objective and objective tasks listed on the right. To meet the Learning object the player must (1) repel the marauding possums, to (2) save the flora and fauna the player will be monitoring the environment, and final to (3) restore the forest ecosystem to its former glory, the player must manage the environment.

Table 6.1 – A Comparison of the Primary Game Goals with the Learning Objectives and Tasks

Primary Gameplay Goals	Objectives
1. To repel an army of mammalian pests led by marauding possums <ul style="list-style-type: none"> <li>○ <i>immediate motivational goal</i></li> <li>○ <i>a player action</i></li> </ul>	Learning Objective - Maintaining and restoring the eco system of NZ forests based on biodiversity conservation.  Objective Tasks -
2. Save the native flora and fauna <ul style="list-style-type: none"> <li>○ <i>midrange goal and motivator</i></li> <li>○ <i>reinforcer of player action</i></li> </ul>	1. Monitor Environment <ul style="list-style-type: none"> <li>i. <i>Assess tree health</i></li> <li>ii. <i>Assess possum impacts</i></li> </ul>
3. Restore the forest ecosystem to its former glory <ul style="list-style-type: none"> <li>○ <i>longer-term aspiration goal</i></li> <li>○ <i>Feedback on actions, indicator of success</i></li> </ul>	2. Manage Environment <ul style="list-style-type: none"> <li>I. Keep trees healthy</li> <li>II. Reduce Possum impact               <ul style="list-style-type: none"> <li>○ <i>Deploy control methods</i></li> <li>○ <i>Assess control methods</i></li> </ul> </li> </ul>

### 6.4.2 Level Goals

The complete design plan for Ora has four levels of gameplay, which deal with the challenges of using only the available tools within limited budgets, ethical dilemmas and meeting the needs of concerned citizens. These are:

- (Level 1) Ground operations; using contractors on the ground to monitor tree, set traps and bait station
- (Level 2) Aerial operations; sowing of bait from to cover large areas
- (Level 3) Managing stakeholders; dealing with landowners, general public and government bodies
- (Levels 4+) Combination of levels 1-3 across multiple land sections.

Typical of most game development projects we operated within a set of constraints namely time and budget. In light of this the gameplay design was focused on Level 1 – Ground operations. In the timeframe of the PhD thesis we were unable to complete the other levels.

Level 1 comprises a 61 hectare area of forest enclosed by a predator-proof fence, mimicking real-world mainland island reserves found across New Zealand. The forest consisted of three native, palatable tree species (kamahi (*Weinmannia racemosa*), Southern rata (*Metrosideros umbellata*) and Hall's totara

(*Podocarpus hallii*) and the initial possum population was set at 20 per hectare with an equal sex ratio. Interactions between trees and possums were controlled by the PSSG model. This model allows the trees to grow and change over time while showing the impacts of possum browse on the forest canopy. In-game possums, also controlled by the PSSG code, move around the gameplay area, with movements dictated by the position of their home ranges. Game time moved at roughly 1 night per second of play, therefore 15 minutes of gameplay could equate to 2.5 years of forest time.

#### 6.4.2.1 Level 1 – Ground Operations

Our Level 1 game goal: To create an area of forest suitable for a kiwi sanctuary; an area that has low to no Possum numbers.

- Outcome: To establish positive tree health and a healthy bird population.  
Action: reduce the Possum numbers in the area
  - Level Epic Win State: All Possums dead inside the fenced area. Trees at 80% health or more. Release of a nurtured Kiwi bird.
  - Level Epic Fail State: 100% Possum health, 20% tree health and/or unhatched egg or unreleased Kiwi bird.

An Epic Win is a gameplay term that describes what happens when the player applies all of their skills in achieving the most ideal outcome possible within the constraints of the gameplay. Kelly (2014) states that ‘epic wins slowly occur over long periods of time’.

To achieve the level goal the player is given access to the ground operations from the PSSG model; Tree Monitoring; Fencing; Trapping; and Baiting. The in-game application of these operations forms the goal orientated skill based tasks of level 1.

#### 6.4.3 Skill Stages and Tasks

The levels are designed to complement the functionality of the mathematical model underlying the gameplay structure. The PSSG model assigns land space in hectares that are displayed in the game world as hexagons. The gameplay for Level 1 is subdivided into four skill stages.

Each skill stage draws upon the ‘Three Phases of Skill Learning’ and the principles of achieving a skilled performance (Bradshaw, 2007; Fitts & Posner, 1967). A skill has five components: (1) the challenge to be undertaken, (2) tasks that contribute to that challenge, (3) feedback on tasks, (4) rewards for task completion, and (5) progression defining the path to the next skill stage. This structure guides the pacing of the goal oriented progression, by building-up the level of complexity and challenge. In Ora the player

begins with a minimum of complexity, starting with only 1 hectare of playable space at Skill Stage 1. When reaching the fourth skill stage they will be playing across the full 61 hectares using the complete range of ground control management strategies.

Level 1 is a tutorial level, sitting in the Cognitive or Early phase of skill learning, ‘Where a learner tries to understand the task and what is being demanded of them’ (Fitts & Posner, 1967). The purpose of Level 1 is to allow the player to learn the game interface, control system and ground operation methods of eco-system management. Figure 6.5 provide a visualisation of the gameplay area and the key skills to be undertaken at each stage. As the figure shows, each skill stage increases the land area that the player has to manage and the tools that the player has to control the possums.

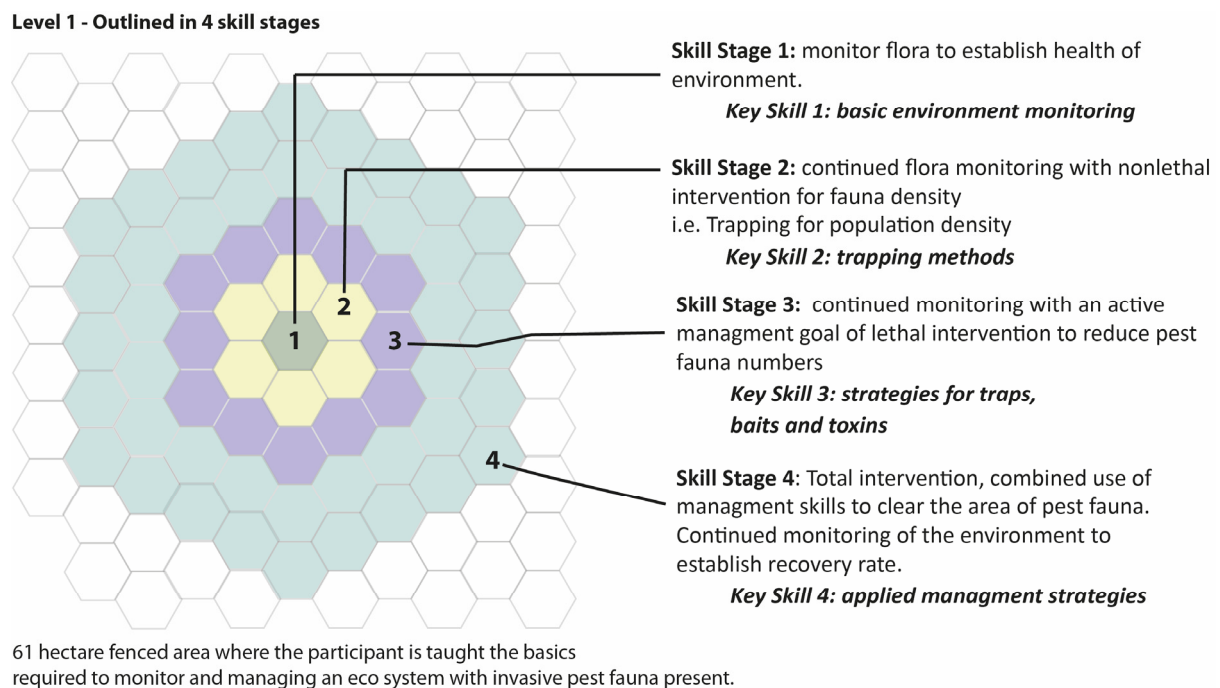


Figure 6.5 - Outline of Skill Stages, increasing in task difficulty and spatial complexity.

#### 6.4.4 Gameplay Features Supporting Gameplay Tasks

With the definition of the skill stages the supporting gameplay features can be constructed. This involves the application of the narrative to tie the gameplay features together. The cohesion of the skill tasks and the user experience is delivered through the design of the User Interface (UI). The **Research Centre**, housed inside our control tree is the primary gameplay setting. It is from this point of view that the player accesses the game controls, 3D forest environment and the feedback and reward systems. This is the location where the player interacts with Liana, the research scientist character, who guides the player through the **gameplay missions**.

#### 6.4.4.1 Rewards and Feedback

On successful completion of a mission the player is awarded science points that are linked to the nurture system. The nurture system is a reward and feedback mechanism. Successful intervention with the skill stage management strategies allows the player to nurture a native bird. In level 1 the player is awarded a Kiwi egg, which they hatch and release into the fenced area that forms the sanctuary. Earning science points increases the hatch rate of the egg, as does removal of Possums from the game world, by application of management strategies. Other indirect feedback systems include the updating the forests tree health status. The health status is shown by visually updating the trees within the game world, when they are negatively impacted by possum browse or positively impacted by management operations.

#### 6.4.4.2 User Experience and Interface

The UI was designed to support all the gameplay features through grouping the components into five areas. The UI places the player inside the control tree, in the setting of the research centre. The UI frame the view of the game-world in the style of a view-screen/window. Figure 6.6 shows the initial plan for the games UI layout.

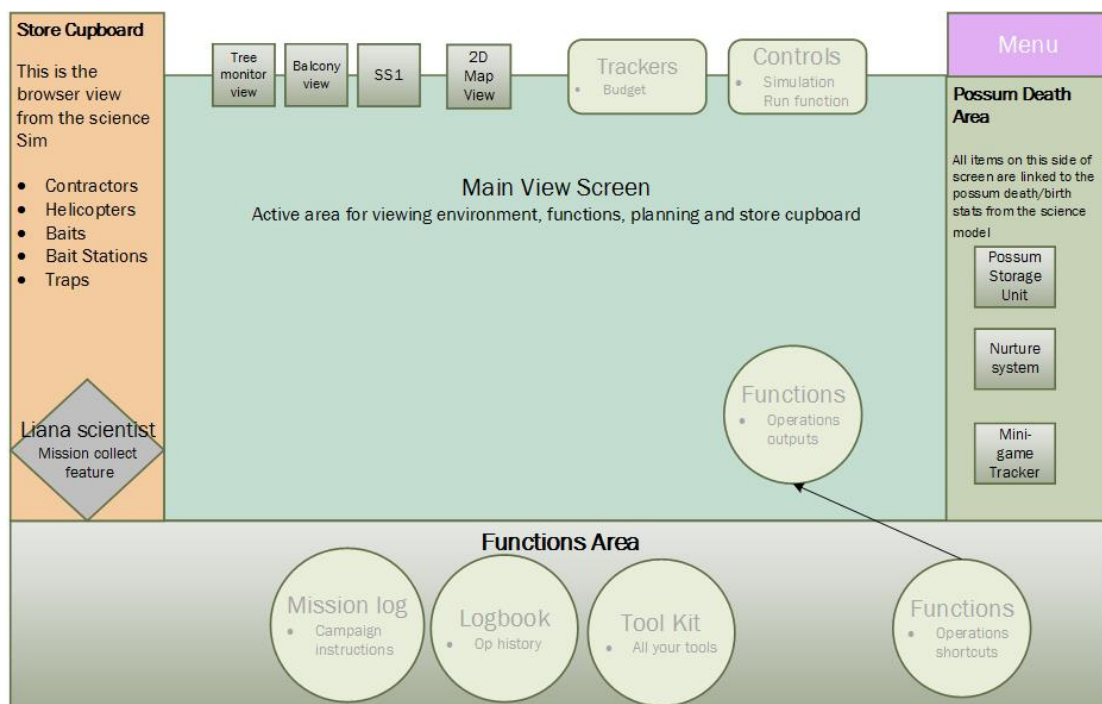


Figure 6.6 - Planned layout of the UI elements before Engine build

- **Main View Screen:** At the centre of the UI is the main view screen. It is the active viewing area of the 3D environment, the tools libraries, operation function panels and the 2D planning screen.



- **Top UI:** Along the top of the UI, from left to right are buttons for swapping between gameplay camera views, the budget tracker and the simulation timeline controls.
- **Left UI:** On the left-hand side of the screen is the Store Cupboard, where all the management tools available to the player are referenced. Interaction with the mission system via Liana is also located here.
- **Right UI:** On the right-hand side we have the gameplay features for reward and feedback. Firstly there is the ‘Pestimate’ a feature that estimates the number of Possums active in the playable area. Below this is the ‘Possum storage unit’ that tracks the number of possums removed from the world via player intervention. Below that the nurture system can be accessed, this opens up the ‘Hatch O’Meter’ which tracks the hatch progress the Kiwi egg.
- **Bottom UI:** Along the bottom from right to left is the functions area. It is here where all the shortcuts for the management operations are located. It also holds the field-kit satchel of mission accessories and icons for the Logbook and Journal. The logbook is provides the history of operations executed and their results. The Journal supplies a list of missions undertaken and their instructions for completion.

Figure 6.7 shows the HOME view of the final UI for the game that was realised from this planning stage.

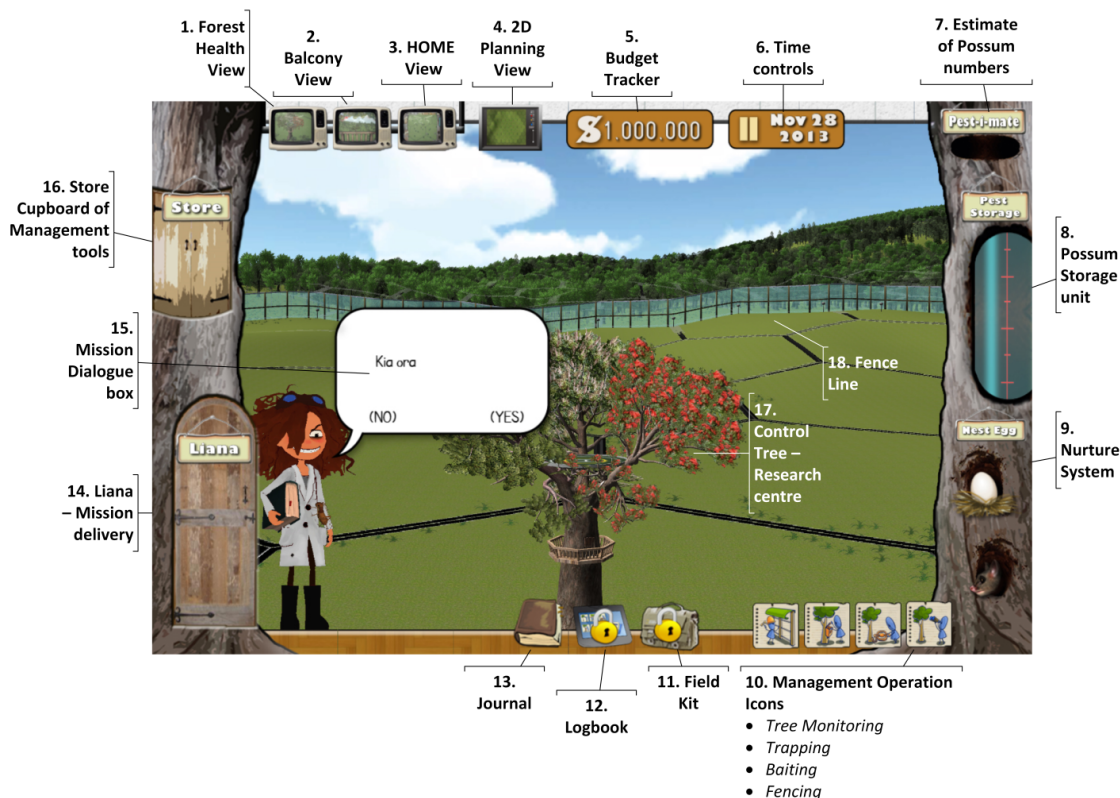


Figure 6.7 - The main UI playing view of the final game build

Tables 6.1 to 6.4 offer further explanation of the gameplay features activated through the main UI. Each table details the set of features from the top, right bottom and left of the main UI. These features are numbered in accordance with the features number in Fig. 6.7 above.

Table 6.2 - Features 1-4 of the top-set UI panel of the game



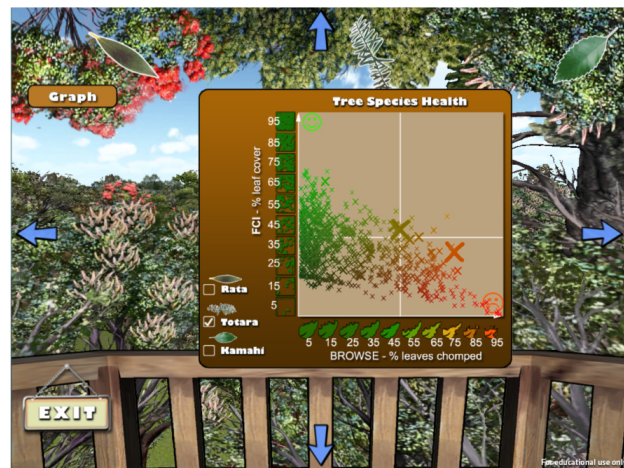
Here the player has an outside view of the control tree which comprises of three native tree species. These trees types are what the player must monitor and protect in this level. From this view the player is also provided with a graph that maps the health of the forest. This graph is updated directly with tree health calculations from the PSSG model. Updates take place each night of model time.

## 2. Balcony view (A)



The control research housing the research centre has a balcony running around it's outside. The player can visit this balcony for an immediate view out over the forest canopy. The view is rotatable through 360° around the balcony. This provides a close up view of tree damage due to possum browse of the canopy. At the top of the UI there are branches from each tree type. The branches have 'leaf buttons' providing the player with a tree identification information and has a possum preference 'tastiness' rating.

## 2. Balcony view (B)



Also found on the balcony is a secondary forest health graph like the one in the Forest health view. This graph can be filtered so that the player may select specific tree types, identifying risks and recovery rates per species. Both of the Forest Health graphs are a gameplay method for supporting the intrinsic motivation of 'Maintaining and restoring the forest eco-system.' This view provides a contextual link for the visual changes of the virtual forest and the graph data. Between these two sources of feedback the player can track possum browse and see management strategy impacts.

#### 4. 2D planning view



The final active window on the top set is the 2D planning screen, providing an overhead view of the forest. It has a timeline slider for the player to view historical patterns of possum deaths, both natural and through management. It can also be used to display the temporal and spatial location of management operations within a 30-day window either side of the selected date-point. This screen is also activated for the set-up of management operations. It offers a simplified view of the 3D forest broken into 1 hectare hexagons.



Table 6.3 - Features 8-9 of the top-set UI panel of the game

8 & 9. Possum Storage and Nurture System



**8. Pest Storage** unit. This displays the number of possums removed from the world via player intervention. Science point awards also count towards hatch rate. The nurture system is the player’s in-game extrinsic motivational link for native bird recovery and achieving the 100% NZ pure perception.

**9. Nurture system**

The nurture system provides contextual information on the ‘Nest Egg challenge’. It informs the player that removing possums from the world helps an egg hatch, linking bird recovery with possum removal. This is visualised through the Hatch O’Meter, which displays the hatch rate between 0% at the Possum end and 100% at the Kiwi end.

Table 6.4 – Features 9-13 of the bottom set UI panel of the game

## 10. Management Operation panels



The final set of icons access the operational panels which is where the player sets the parameters for their management strategies. In these panels they are able to choose common features such as helicopters and contractors alongside operation specific features, such as number of tree to monitor. They are then able to get a quote for costs and time before choosing to run the operation. These panels provide direct interaction with the PSSG science model running under the gameplay.

## 11. Field Kit



The Field Kit is a container for mission items. The items are stored in a bag system which the player can access when needed. In the example above the field kit allows access to the 'FCI chart', an item that enables player assessment of forest health. Together the mission items in the field kit provide a collection of tools for interpreting and interacting with the environment and support player skill learning.

## 12. Logbook



The logbook holds a record of all the management operations undertaken. It is comprised of a calendar linked to the timeline slider, and a list of operations with the selected operation displayed in red. Selecting an operation displays its details in the next window, including parameters such as equipment, duration and cost. The final window shows the operation results. For a tree monitoring operation it would provide a list of the trees types and their health at that point in time. The 2D Planning screen also displays the selected operations map location data.

## 13. Journal



The left page of the Journal provides the current and historical Mission list. The active mission is at the top and previous mission below. On the right-hand side are the mission details. These provide the simple instructions first, then more detailed mission context below. They also provide the mission steps where required.



Table 6.4 – Features 14/15 - 16 for the left-set UI panel of the game

14/15. Liana



Liana provides the missions and guides the player. She is the embodiment of the engine mission system. She can be dismissed and recalled by the player by clicking on her door. Liana’s Dialogue box is the mean by which the mission information is presented to the player. The box is interactive with player clicking on options within the box as with the (No) (Yes) examples in the image.

16. Store



The store provides a searchable list of resources that the player has at their disposal for conducting management operations. It provides details for each tool set, such as the specialities and cost per hour of the contractors. This helps the player make informed choices.



## 6.5 Engine Space

In the Design Space we outlined the primary game goals and level plan of the project. For this iteration of the game build the intention is to focus on level 1 - Ground Operations. Level 1 has four skill stages. Player progression through the skill stages focuses on creation of an area of forest suitable for a kiwi sanctuary. The Engine Space provides the structure for the designers' mission mapping, which in turn guides the coding of the in-engine mission-system. This is an explorational approach where the designer works closely with the coding team to realise the gameplay mechanics.

### 6.5.1 Skill Stages

This section falls between the Design and Engine Spaces but it is, in essence, a combination of both. Its content is generated from the iterative process of mission planning that draws on both the content of the Design Space and the structure from the Engine Space.

Figure 6.8 follows the structure of the SPP 'spaces' to illustrate the development of 'Skill Stages' into 'Mission sets'. Level 1 of our game has four Skill Sets and therefore four mission sets. To illustrate the process we'll be using Skill Set 1 as our example.

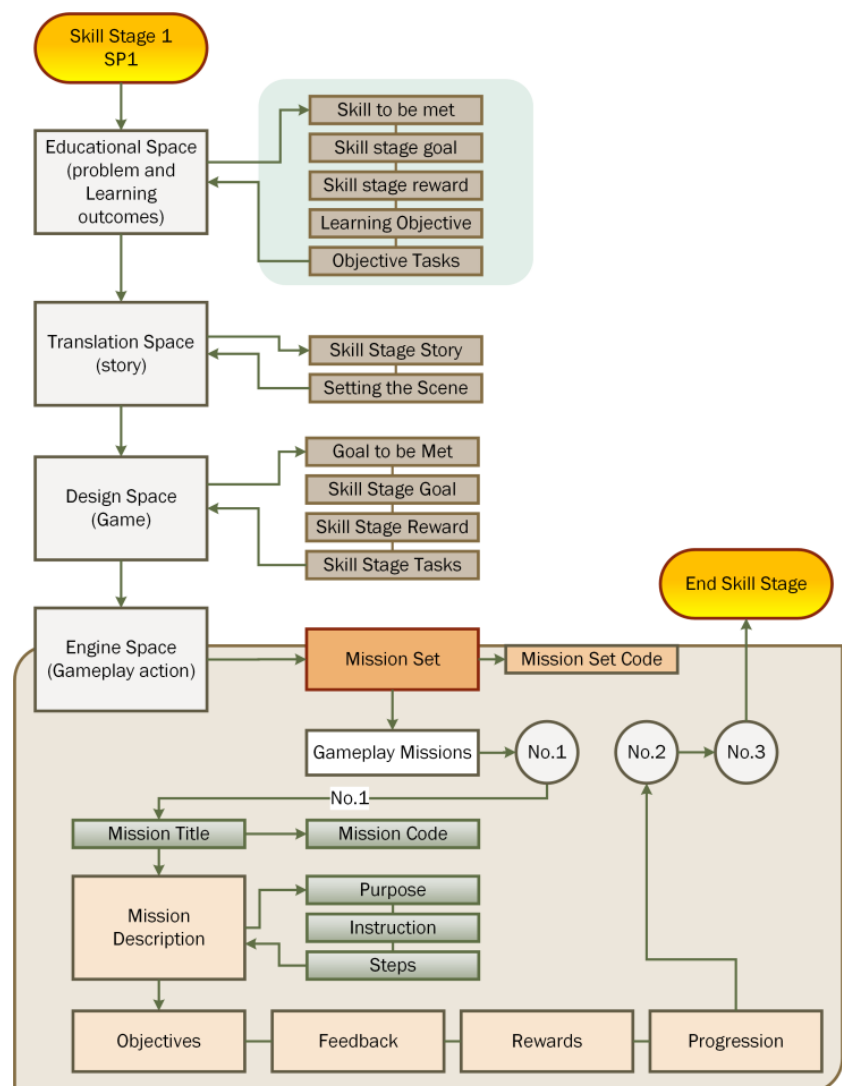


Figure 6.8 - Structure of the Skill Stage - Mission Objective documentation

The Skill Stage - Mission

Objective document (Table 6.5) provides the designer with precise details of the mission features to be developed into game mechanics (see section 1 for the definition of game mechanics). It also provides a discussion and communication document that supports both design and coding roles.

In Table 6.5 we present a sample of the documentation that follows the structuring seen in Fig. 6.8. In this example we begin at the Mission Set juncture (the boxed area in Fig. 6.8), and details the content and intentions for Mission 1.

Table 6.5 - An Example from the Skill Stage Mission Objectives documentation

1. ENGINE SPACE - Gameplay Action Space			
Mission Set (campaign)	Environment Monitoring	Mission Code	EM
Gameplay Missions	<ul style="list-style-type: none"><li>What trees need to protection?</li><li>How healthy are they?</li><li>Put up our fence</li></ul>		
Mission Title – Protect and Preserve!		Mission Code: EM1	
Mission	<p>Identify the trees to monitor</p> <p><b>Purpose:</b></p> <p>(1) to get user to experience and grasp the functions of the balcony view interface</p> <p>(2) Familiarise with tree type to be monitored in our forest section</p> <p><b>Instruction:</b></p> <p>Collect 3 falling leaves and match them to the tree branch they fell from. (Use the Id card from Field Kit to identify our tree types.)</p> <p><b>Mission Steps:</b></p> <ul style="list-style-type: none"><li>Use left/right scroll function experience 360 view from balcony view.</li><li>While scrolling to collect falling leaves</li><li>Use ‘identity card’ to match the leaf to reveal the tree type</li><li>Once matched – fallen leaf moves back to tree branch and acts as an info button linking to text on this the tree species – Button glows to show it is an active button. Mission is complete when the tree ID button is clicked on.</li></ul>		
Objectives	<ul style="list-style-type: none"><li>Identify Southern Rata</li><li>Identify Halls Totara</li><li>Identify Kamahi</li><li>Activate tree info buttons (links to tree info achievement) – this could be part of science level achievement title?</li></ul>		
Feedback	Feedback is in the form of detailed information on the tree species through the activated buttons. These buttons are active as reference points from the balcony view only.		
Reward	Unlock Nurture system the ‘empty’ nest ready for receiving egg		
Progression	Is context for the ‘Tree Monitoring Operation (TMO)’ Provides player with knowledge of the tree types and unlocks the Tree Species section of the TMO GUI.		

In Fig. 6.9 below we see the mission logic diagram for mission EM1. This is the initial translation of the information in Table 6.5 into a set of steps that describing the gameplay structure in terms of game engine application.

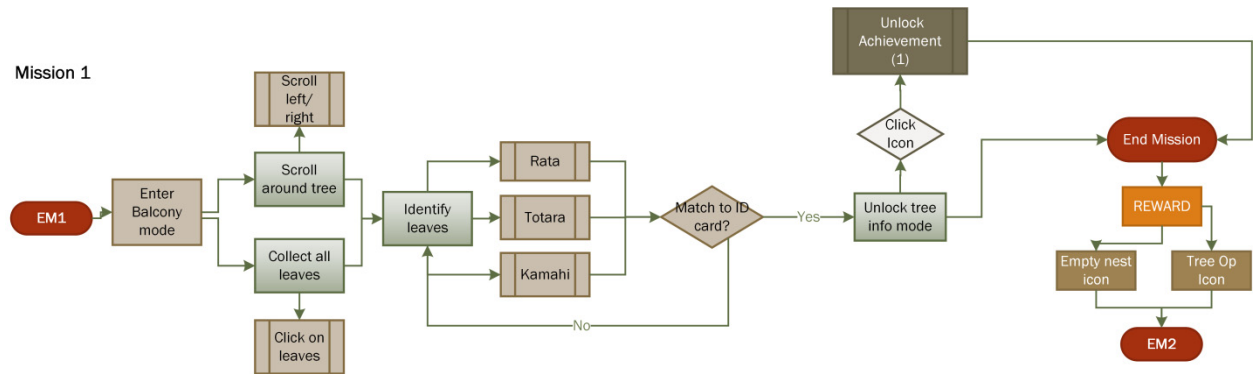


Figure 6.9 - Mission EM1 logic diagram pre-engine proposal

## 6.5.2 Gameplay Missions

Game Engines do not include a readily prepared mission system for gameplay implementing. The remit of our game coder was to implement the mechanics and mission logic into the engine to meet the design specifications. On reaching this point in the design process the designer has created the documentation that describes the missions of the four Skill Stages. This documentation follows the structure outlined in Fig. 6.8 of which table 6.5, Mission 1 (EM1) offers an example. We will continue to use mission EM1 as a means of illustrating the game engine mission structure. Before entering into the specifics of an individual mission we present the mapping of the engine side mission control system.

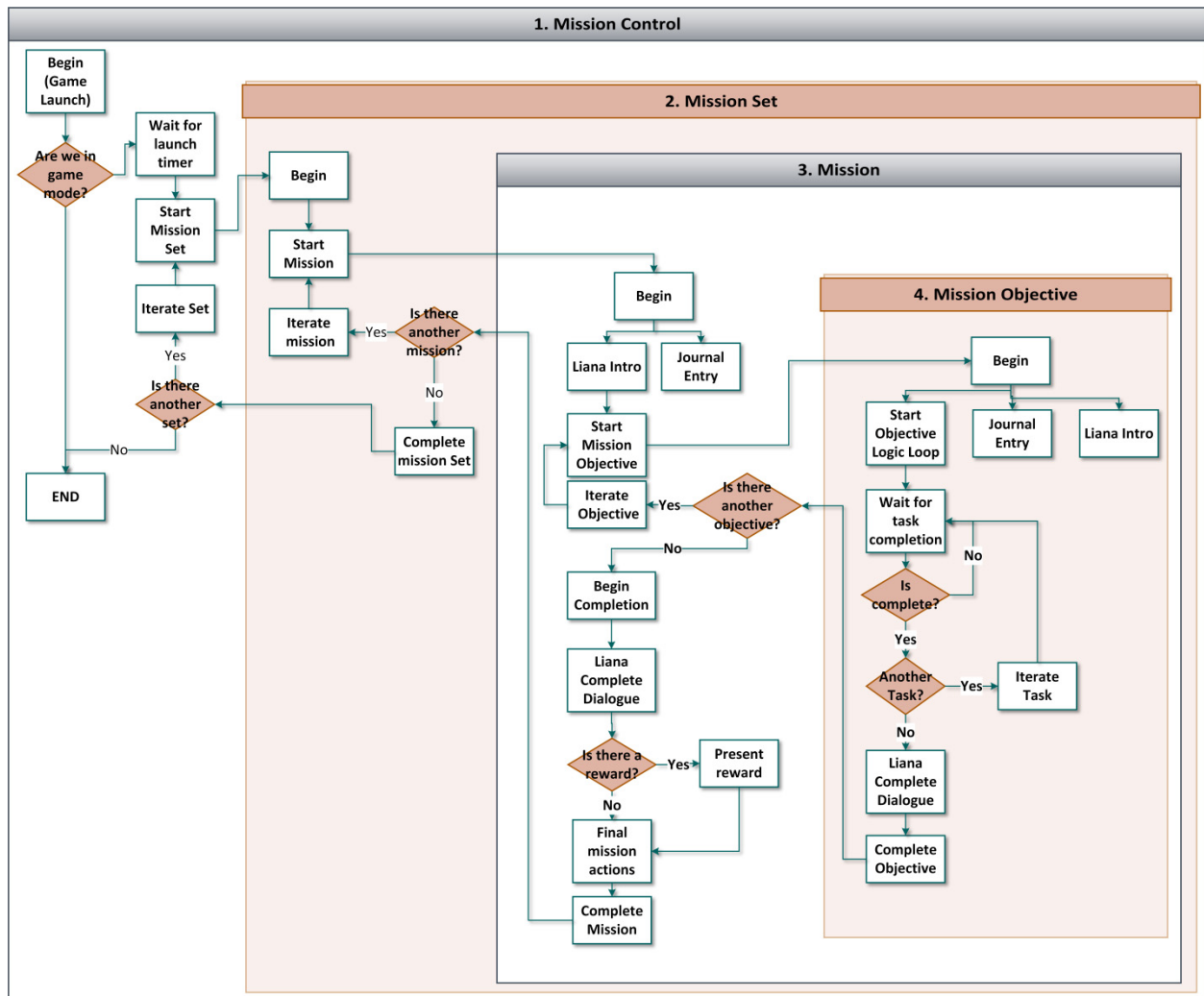


Figure 6.10 - Ora Engine side mission control system logic sequence

The mission system developed for the Ora game in following the SPP approach comprises of the four step hierarchical system shown in Fig 6.10.

This is comprised of;

1. **Mission Control** which has various controls for setting gameplay parameters that apply for the entire gameplay level. In the gameplay the mission controller initiates mission sets, checks for completion, then iterates a new set or ends the gameplay. Nested within the mission controller is;
2. **The Mission Set:** The Mission Set holds all of that sets of related missions. These are the missions defined under the relevant Skill Stage; here we explore Level 1, Skill Stage 1 - Environmental Monitoring, previously shown in figure 6.8. The Mission Set provides the same functionality as Mission Control in checking and instantiating all the missions linked to that Mission Set in the design.
3. **Missions;** Clustered in the Mission Set are the Missions. We are using the example here of EM1 – Protect and Preserve that teaches the skill of identifying the trees to monitor. The mission

starts by triggering the Liana Intro dialogue and the Journal entry. Liana is the onscreen mission delivery system for the player, and the Journal outlines the deeper levels of player guidance.

4. **Mission Objective;** When the player completes their interaction with Liana the Mission Objective is triggered. The Mission Objective houses the tasks the player will undertake in the gameplay. On completion of the Mission Objective the logic either starts the next objective in the sequence or begins the mission completion sequence. The completion logic provides feedback dialogue to the player from Liana about the outcomes of the mission. It then triggers the reward and any other feedback systems that are linked to that particular mission. The Mission is then flagged as complete and triggers the next Mission in the Mission Set.

#### 6.5.2.1 Mission Logic Screenshots

Fig. 6.11 shows a screenshot of the Mission System from within the Unity Game Engine Editor showing the designers' view of the gameplay world through the game engine interface. This interface is where the mission parameters are edited. The mission system interface is on the right and the two views of the game world are on the left. The numbers in figure 6.11 show the following elements:

1. The level editor 'Scene' view. The designers perspective of the user interface while editing the scene
2. The 'Game' view showing the gameplay world as laid out before the gameplay is running
3. The 'Hierarchy' view showing the Mission system hierarchy for the Mission Set – Environmental Monitoring (EM)
4. The 'Inspector' view showing the designers view of the Mission EM1
5. The Project folder containing all the items included in the game project. This screen shot shows the list of scripts that the run the science simulation that control the possum/forest interactions.

## Game Engine View of Mission EM1

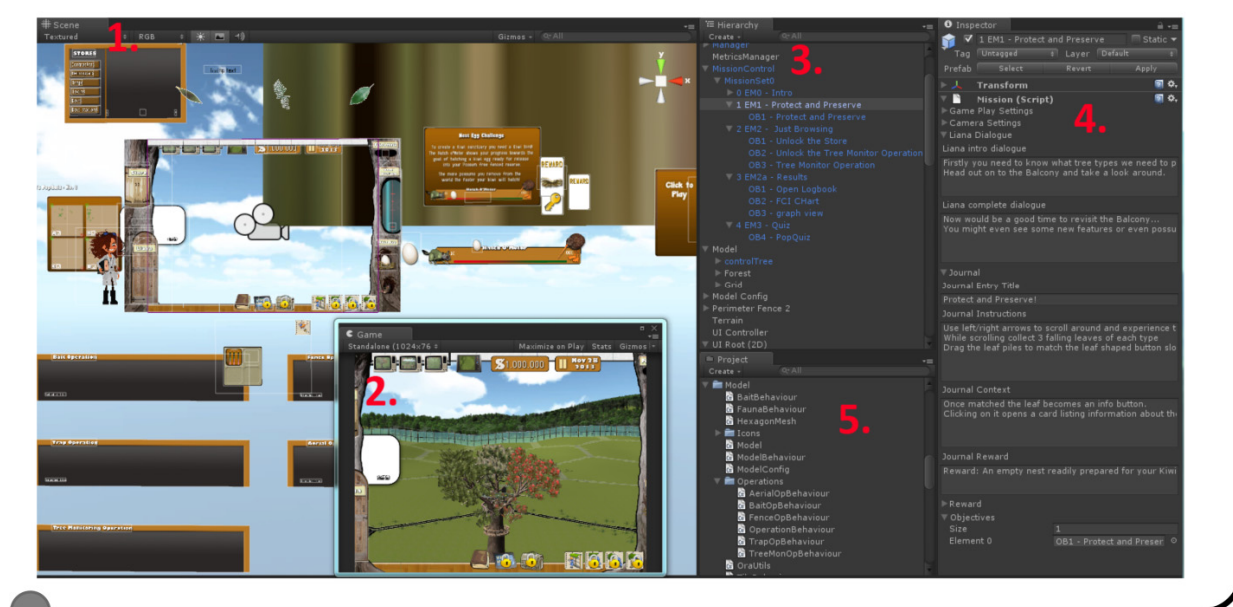
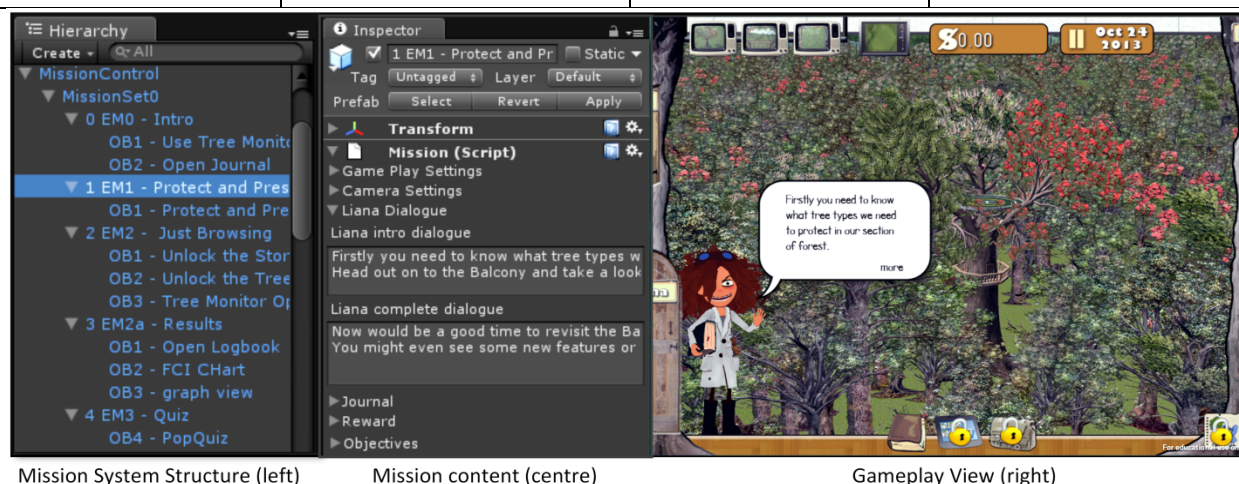


Figure 6.11 - Designers view of the game world as seen in the Unity3D game engine

Table 6.6 and Fig.6.12 outline the gameplay Mission EM1 providing the context for the set of screenshots in Figures 6.13 to 6.19. The screenshots illustrate the connection between the Engine side mission control system logic sequence of Ora (Fig. 6.9), and the Unity3D Game Engine Editor view of Mission EM1 game engine perspective of the designer.

Table 6.6 – Outline of Mission EM1

Mission	Objectives	Reward	Progression
EM1 - Protect and Preserve!	<ul style="list-style-type: none"> <li>Identify Southern Rata</li> <li>Identify Halls Totara</li> <li>Identify Kamahi</li> </ul>	Unlock Nurture system the 'empty' nest	Unlocks the Tree Species section of the GUI



Mission System Structure (left)

Mission content (centre)

Gameplay View (right)

Figure 6.12 - Engine Editor view of the mission control system (top left), and example of EM1 mission dialogue in the editor (bottom left) and gameplay view (right)

## 1. Mission Control

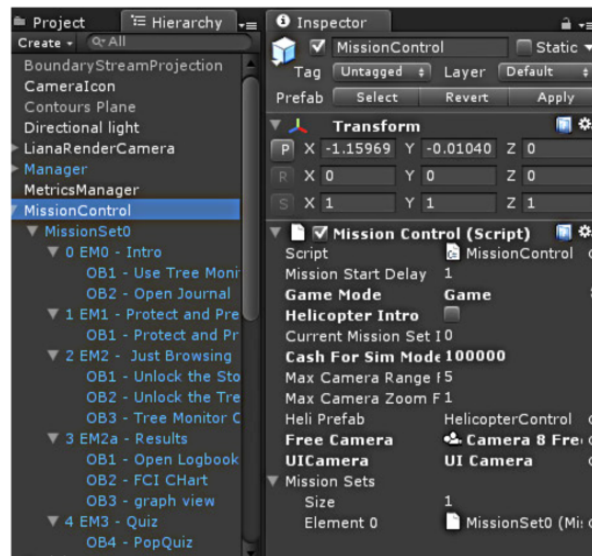


Figure 6.13 - 1. Mission Control system

1. The Mission Control heads the Hierarchy (left) and set parameters for the missions in the game (right)

## 2. Mission Set

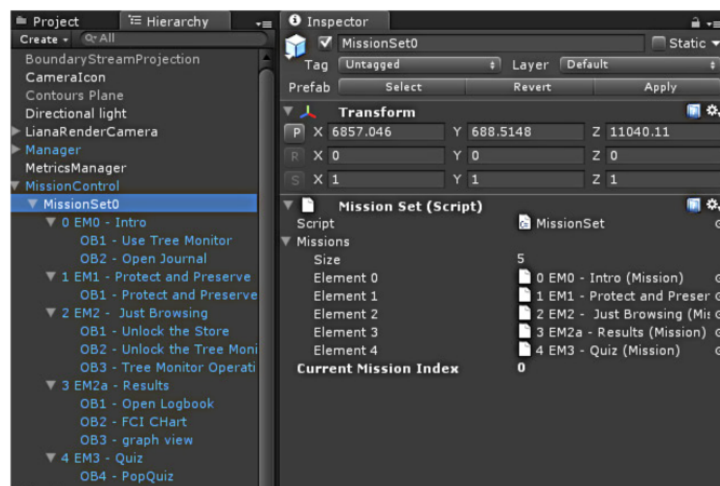


Figure 6.14 – Mission Set

2. Mission Set - Highlighting the Mission set on the left brings up the missions lists for that set on the right



### 3. Mission - EM1 – Structure

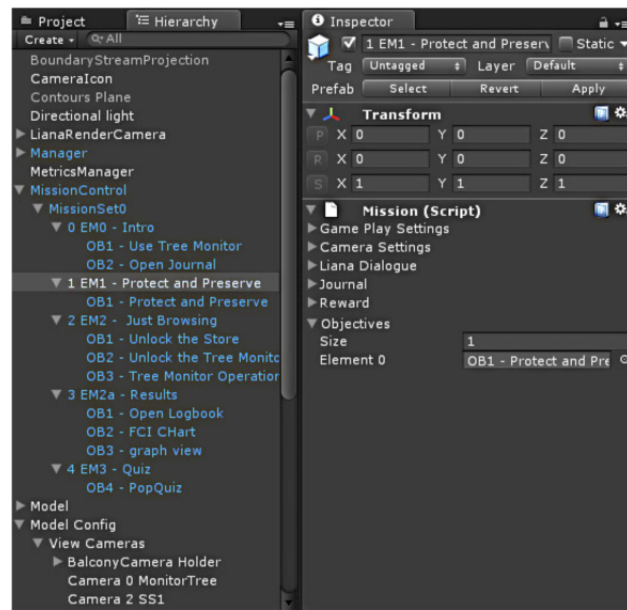


Figure 6.15 – Structure of Mission EM1

3. Mission EM1 – Structure: Highlighting a mission brings up all the mission fields on the right

#### 3a. EM1 - Liana Dialogue

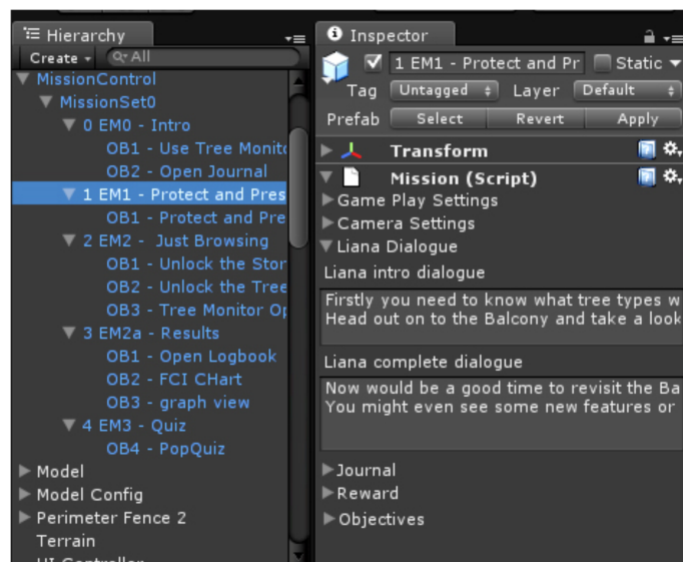


Figure 6.16 – Liana Dialogue EM1

3. Mission EM1 - Liana Dialogue: This is where the player facing Liana mission dialogue is entered



## 3b. EM1 – Journal

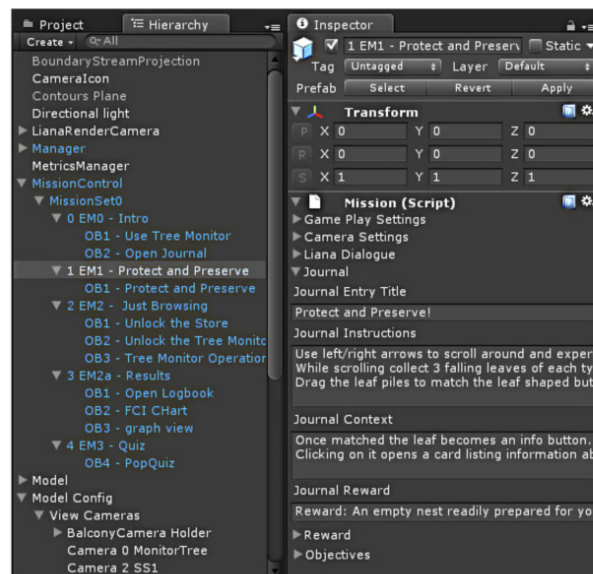


Figure 6.17 – Mission EM1 Journal text

3. EM1 Mission – Journal: Expanding the Journal tab allows entry of the player facing journal text

## 3c. EM1 – Reward

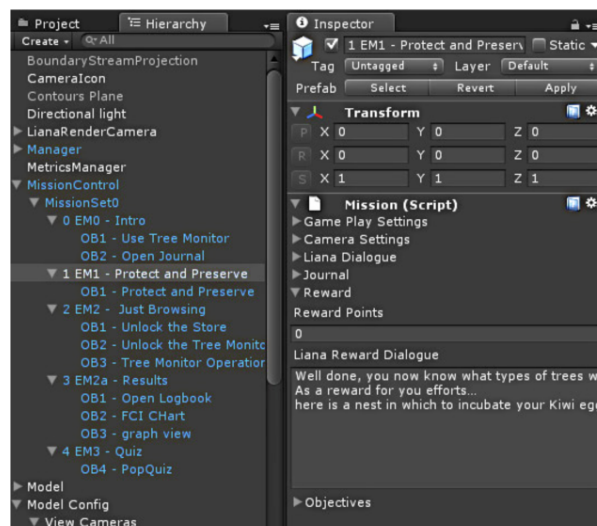


Figure 6.18 – Mission EM1 reward Dialogue

3. Mission EM1 – Reward: The reward field allows for points allocation and any reward player facing dialogue

## 4. Mission Objective

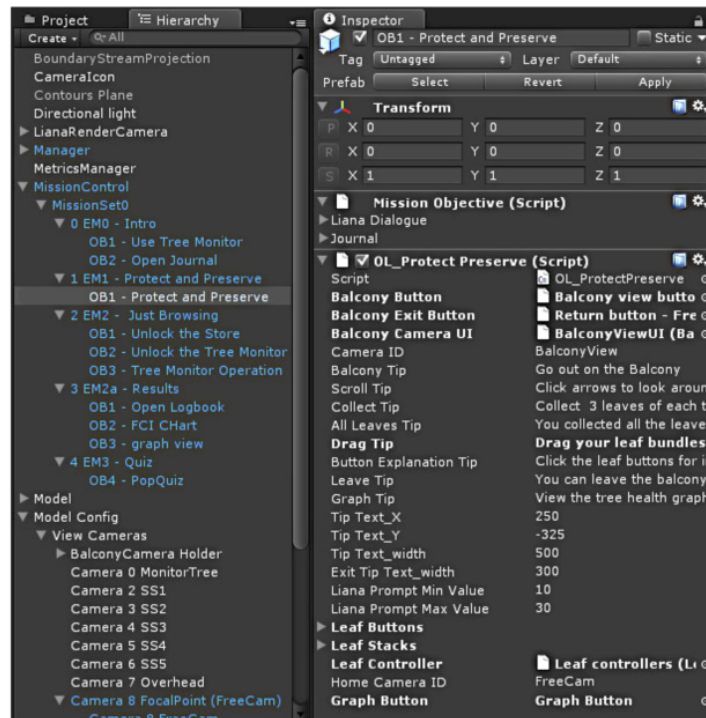


Figure 6.19 – EM1 Mission Objectives

4. Mission Objective - This section allows for additional Liana dialogue and Journal entries that might be required for the objective. The objective is the section where custom scripts are placed for controlling the differing interactions required for each set of objective tasks. These tasks are normally unique to each mission and require individual scripts to control the gameplay interactions. In this screenshot we see a range of onscreen tool tips to guide player actions. But these can also include script parameters for mini games as in the case of EM1 and its leaf collecting mini-game.

### 6.6 Conclusion

In this chapter we have provided an overview of the how the Structural Playability Process (SPP) was followed as a design approach in the creation of real gameplay. We have shown how it is possible to follow a process from the very highest level, developing a learning gameplay that can be implemented into a game engine.

The four spaces of the SPP; (Education, Translation, Design and Engine) provide a practical approach for translating a real-world client 'problem' into an effective educational gameplay environment. The use of motivation theories (Csikszentmihalyi, 1990; Deci & Ryan, 1985; Abraham H. Maslow, 1999) to define

learning outcomes, objectives and tasks provides a useful framework for structuring a narrative which leads to clear gameplay goals.

The use of skill stages (Bradshaw, 2007, 2010), supported by the application of skilled performance theory (Fitts & Posner, 1967), links the Design and Engine spaces and provides the structure for mapping the Mission Sets and their system of challenges, tasks, feedback and rewards into effective gameplay. The implementation of the Mission Set structure into a game engine then provides a system that supports player progression and achievement of the gameplay goals.

The Design and Engine Spaces are practical, straight forward, and general enough to be applied to any serious game concept. However, considerable collaboration is required by designer and client to work through the first two stages of the Educational and Translation Spaces, to build an effective narrative on which to hang the game. For a game designer not well versed in educational academic research methods, the initial mapping of learning outcomes could prove challenging.

Returning to the research questions, we conclude that the SPP can be followed as a guiding approach to a real-world client problem. However, it takes considerable collaboration on the part of the designer and client to work through the process. For a game designer not well versed in educational academic research methods, the initial mapping of learning outcomes could be difficult.

In answer to the second question, is it possible for a designer to follow the process and implement the learning outcomes and objectives into a playable design? We have displayed that it is very much possible. Having a gameplay narrative and clear level goals supports the job of the designer making it easier to implement a clear set of player missions.

In our next chapter we undertake a user study that tests the effectiveness of our gameplay design and implementation. We attempt to answer the other development question; does the game meet the learning outcomes of the client, through providing the Target Audience with an engaging gameplay experience that provides subject knowledge?

# 7

## Ora - Save the Forest! User Study

In the *GeoThermal World* user study we used a real-world experience of tutor-led teaching as an exploratory baseline from which to compare a virtual-world gameplay experience of the same nature. In this study there was no real-world experience of Possum management in which large groups of the public could participate. The only comparable reference would be community meetings or scientific papers, which would not provide a suitable exploratory baseline experience for immersive, participatory gameplay. This led to the decision to create a simulation-driven version of the Ora game, which would provide a similar digital experience of the topic. In choosing this method we remove some of the confounding variables that we encountered in the *GeoThermal World* study e.g. where we had a real-world experience providing a baseline for a digital one.

To ensure comparability with the *GeoThermal World* study we designed the ORA experiment to follow the same set of experimental procedures. This allowed us to draw inferences about the validity of the underlying design process, even though the gameplay topic, playing style, and the user interface were different.

The purpose of this study was to investigate the effectiveness of a computer game (ORA), compared to the baseline of a visually rich computer simulation model (PME). For learning about pest management and forest health in New Zealand. The intentions was to investigate what, if any, was the impact of the Structural Playability Process (SPP) design approach on participants knowledge acquisition, and their ability to achieve the various conditions of a Flow state. Both conditions shared the user interface and 3D world environment, along with the functionality and capability of the scientific model embedded in the both digital worlds, that governed possum/forest interactions.

The core difference between the two systems was the application of the SPP designed gameplay in the ORA condition. The PME shared the same functions as ORA but included no gameplay mechanics and

did not use SPP. ORA was based on a system of missions, in-game tasks and rewards, structured by rules and goals. In comparison PME, had no gameplay, no rewards and no rules.

The teaching aim was for participants to learn how to monitor flora to establish the health of the forest environment, with the key-skill being basic environmental monitoring in the context of possum management and control. To achieve this aim the two conditions shared the same set of learning tasks:

- To find out what impact the possums were having on the trees.
- To assess which tree species needed protection.
- To monitor the current health of those trees.
- To analyse what extent those trees were being eaten by possums.

## **7.1 Research Questions and Hypotheses**

The research question under investigation is the third development question:

Will the games when complete meet the learning outcomes of the client through providing the Target Audience with an engaging gameplay experience that provides subject knowledge?

In answer to this question learning gains, participant perception, and game/simulation metrics were collected before, during, and after using both conditions, and the results compared against each other.

### **7.1.1 Objectives**

Objectives were twofold:

1. To investigate the level of knowledge acquisition, task-based learning objectives were delivered through two similar conditions the game-led ORA and tutor-led PME.
2. To investigate motivation and enjoyment impacts on participants of the self-directed SPP computer game ORA, compared against the exploratory baseline data of the tutor-led PME simulation.

### **7.1.2 Hypotheses**

- H7.1:** That a computer game experience of pest management and forest health, designed using the Structural Playability Process (SPP), provides a learning environment that supports positive knowledge acquisition.
- H7.2:** That a computer game experience of pest management and forest health, designed using the Structural Playability Process (SPP), provides a learning environment that promotes conditions for a state of optimal experience, or 'Flow'

## 7.2 Design of the Experiment

This study was of between-subjects design and comprised of two testable conditions. The experiment looked at the effects of a digital pest management learning environment (a scientifically modelled interactive forest environment) on perception of possum control. The environment was the independent measures variable, with the experimental group using the game version (ORA) and the control group using the simulation version (PME). The dependent measures were determined through survey.

The basis of the experiment was to collect data that allowed us to drawn inferences about whether the SPP process had caused the software to have certain properties that are empirically measurable. This data would then be compared against the exploratory baseline data of the similar PME environment.

The experiment was designed to be as similar as possible between conditions to limit variables in setting that could skew data on the impact of the SPP designed gameplay.

Unlike the GeoThermal World game, both treatments had equal populations and gender balance. In addition we collected a range of demographic data such as age and education alongside the collection of level of technology familiarity and computer gameplay experience. The final data set collected was on the usability of the system. These were the four dependant measures:

- **Dependant Measure 1 - Skills Test, pre/post activity**

The experiment looked at the effects of the learning environment on knowledge acquisition. The dependent measure was determined by an exam of pre and post-test scores measured on a knowledge test assessing forest health. As in the previous study, the level of knowledge acquisition was established through a normalised delta score of participant learning gains, applying Hake's (1998) learning gains formula to calculate the degree of change.

- **Dependant Measure 2 – Knowledge retention**

A repeat of the skills test to measure the level of knowledge retention after a four week break.

- **Dependant Measure 3 - Participant Enjoyment on Flow Conditions Questionnaire**

The experiment looked at the effects of learning environment on Flow criteria for participant enjoyment. The dependent measure was determined by a post-activity questionnaire comprising of 27 individual questions collated under 9 category headings.

- **Dependant Measure 4 – Pre/Post Perceptions on Possum Control**

The experiment looked at the effects of the pest management learning environments on perceptions of Possum Control. The dependent measures score was determined by a pre-activity survey, followed four weeks later by a follow-up survey.

### 7.3 Participants

Participants were recruited via an online recruitment publicised through networks associated with the University of Canterbury and Landcare Research Ltd. This led to over 90% of participants having a university education, with 46% of those having done a post-graduate study. The sign-up sheet identified participants by email only, to reduce any inadvertent bias introduced via the researcher's familiarity with the University of Canterbury networks. The only information required was gender, to allow for balancing between conditions.

There were a total of 52 participants, split equally between the two groups, with a gender ratio of 14 males to 12 females per group. The majority of participants were in the age range 18-34. The ORA game condition had a slightly younger demographic with 58% in the 18-25 range, compared with the PME at 42% between the ages of 26-34. We collected information about the familiarity and level of comfort with technology, and experience and comfort with computer games. A total of 90% of participants scored between feeling confident and very confident in their use of technology, with 15% of those in the very confident range and no one scoring as not comfortable with technology. Fig. 7.1 displays a chart showing the percentage of the computing devices that our sample own or use.

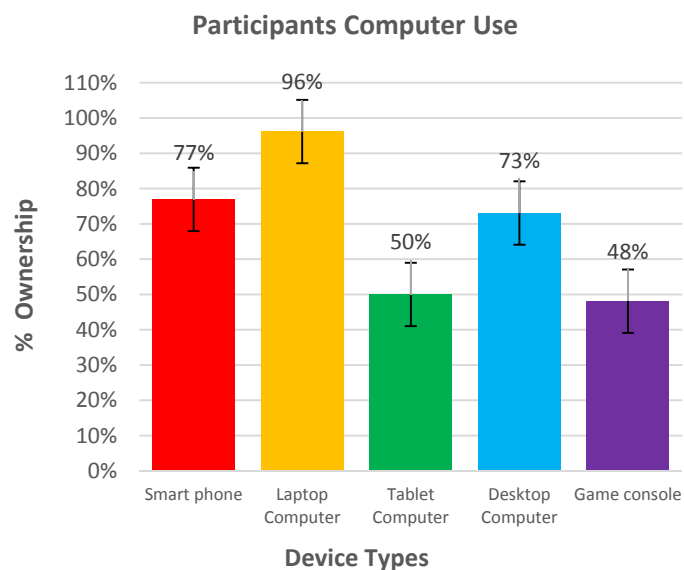


Figure 7.1 – Degree of computing use

When asked about gameplay and gaming skills 88% of participants scored between comfortable and very confident in their gaming abilities. Most participants had played games on various different devices Fig. 7.2, with the majority having previously played games on a PC using a keyboard and mouse.

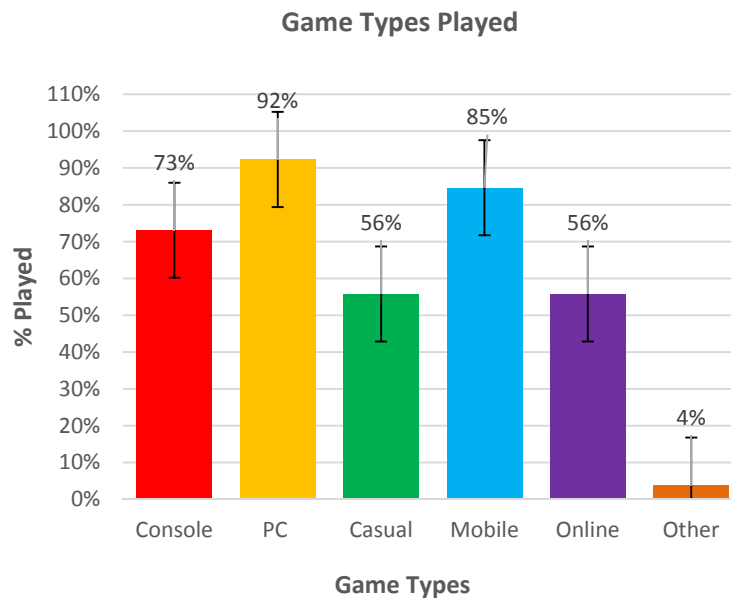


Figure 7.2 - Range of game types played

On the topic of Pest management and awareness of the possum problem in New Zealand forests we found that 28% of the subjects had lived or currently live in a rural location. These people would have been more exposed to possum activity than those in an urban setting. This was split relatively evenly across the groups, with the PME at 27% and ORA at 31%. A large proportion of subjects at 71% said they undertook outdoor activities such as hiking, hunting or fishing, where it would be possible to be exposed to pest management signage and tree damage due to possum browse. Of those, the ORA condition had 61%, and the PME 80%, giving a slightly higher proportion of subjects in the PME who could have been more familiar with the topic. When asked if they had researched the topic prior to the experiment 15% of ORA and 23% of PME participants said yes.

Pre-activity we asked the participants a range of questions regarding their perceptions on the topic of possum control and management. These perception results were then scored to provide a baseline that described the participant's general mind-set towards possum management and control.



### 7.3.1 Participants Perceptions of the Domain Topic

Figure 7.3 shows an average collective scores across all the possum perception questions. A higher score equates to the participant having a higher level of concern/understanding about possum control and management. Most of our participants fell within the medium to high range of understanding and concern. Therefore, we began with a sample that was generally aware but not necessarily informed about the topic of the activity.

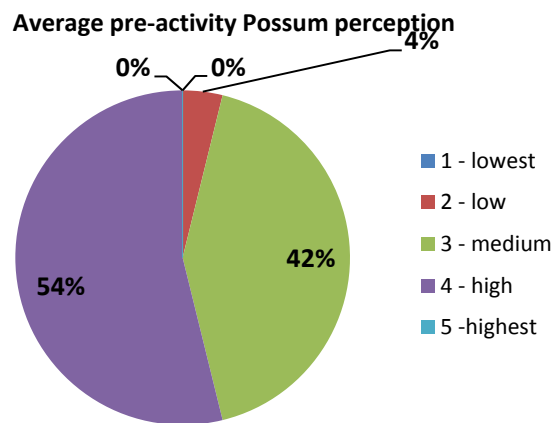


Figure 7.3 - Overall level of understanding and concern about possum control

## 7.4 Methodology

The study took place in a conference room setting accommodating up to 4 participants, each with access to an individual PC. The PC's were arranged along one side of a conference table facing a projector screen. This setting was used for both study conditions; Ora game, and PME simulation. Participants were not made aware of which study condition they would be undertaking. The study was run in sessions with all participants of that session undertaking the same condition. A projected slide provided a reminder that participants could ask for help from the researcher at any time, and a breakdown of the study's tasks and their timeframe. See Fig. 7.4 and 7.5 showing how the conference room was set-up for each conditions session. The only initial difference was the addition of headphones in the ORA condition. An ID code was allocated to each workstation prior to the participants' arrival, which they were required to enter into both the online survey, and to log-on to the computer activity. Both the PME and ORA environment were run in a window with a screen resolution of 1280x960 and the graphics quality was set at 'fantastic'. The environments' keyboard navigation and mouse controls were printed out and placed under each monitor as a visual reference.



Figure 7.4 – PME condition



Figure 7.5 – ORA condition

**Condition 1 – PME** or Possum Management Environment is the computer simulation model. This session was a tutor-led session delivered in classroom teaching format (See Fig. 7.6 and 7.7). The content and instruction was delivered via PowerPoint presentation and the whole activity lasted approximately 15 minutes.



Figure 7.6 - Instructor-led PME session



Figure 7.7 - PME - start screen

**Condition 2 – ORA** or Ora – Save the Forest the computer game. The gameplay was designed to be self-explanatory, with tasks and guidance delivered via the non-player character Liana, seen in Fig. 7.8. As the experience was participant-led it took between 15 and 25 minutes to complete.



Figure 7.8 - ORA session start screen

## 7.5 Study Parameters

The experiment was conducted to help us understand if the structural playability process (SPP) was an effective method of design. The gameplay of ORA was designed to meet the learning objective for skill stage 1 - monitor flora to establish health of the environment (refer to section 6.4.3), with the key skill of learning basic environmental monitoring in the context of possum management and control.

The PME session tasks were paralleled to the task structure delivered in the gameplay. The core learning task was to undertake a tree monitoring operation and then to review and assess the results. Table 7.1 below lists the shared experimental tasks for both the PME tutor-led condition and the gameplay self-directed ORA condition.

Table 7.1 - List of Tasks

Tasks	
1	Familiarise with setting and User Interface features
2	Establishing the problem, game goals and task
3	Identifying tree species to protect
4	Familiarise with available equipment
5	Undertake a tree monitoring operation
6	Review the results of the operation
7	Use the FCI chart to assess the results
8	Compare the FCI chart to the forest health graph to judge the health of the forest and the level of possum browse – has the game goal been met?
9	Undertake quiz to test knowledge learnt from the task.

## 7.6 Materials

Several sets of materials were developed to assess the dependant variables. The materials were accessed online via Qualtrics survey software. On the day of the study the information collected comprised of general demographics including; data on technology usage and computer game experience, perceptions of possum control, pre and post activity knowledge tests, the Flow survey, and a user interface survey known as the System Usability Scale (SUS) (Bangor, et al., 2008). A follow up survey link was emailed to participants approximately four weeks after the study, which asked questions on perceptions of possum control and included a repeat of the knowledge test for assessing retention.

### 7.6.1 Knowledge Acquisition

The knowledge acquisition skills test questions were devised by the author's co-researcher Dr. Pen Holland; a researcher in wildlife ecology and management at Landcare Research Ltd. The knowledge test was designed to allow for different learning styles (see section 3.3.3.1), and to present a range in the level of depth and unique answers. The test was designed to assess the participant's knowledge of observation and measuring skills needed at forest health management, before and after the activity.

The questions were grouped in to three types:

- **Type 1: Short Answer** - Observation and reasoning. For example:

List as many types of observational data (information) as you can that could be collected from a tree monitoring operation (hint: consider what you could measure or estimate by looking at the tree trunk, branches, leaves and flowers/fruit). For each type of data, write the reasoning or purpose for collecting it.

There were eight opportunities for listing observational data such as; foliage density, percentage of leaves eaten, etc. Each observation was awarded 0-1 marks and a score of between 0-4 was awarded for the depth of reasoning provided. An additional score of between 0-5 was allocated for items mentioned specifically in the game/sim for a total of 45 marks. See Appendix C.1 for the marking scheme.

As in the case of *GeoThermal World* this style of question (open-ended; short answer) was purposely included as it provided not only awareness of items, but the depth of reasoning not possible with multiple-choice style questions.

- **Type 2: Multiple choice** - There were six questions carrying a total mark of 18 marks. Questions ranged from asking *‘how could you measure tree canopy health?’* to *‘which tree species is the least tasty to possums?’*
- **Type 3: Visual choice** –This question explored visual reasoning (Fig. 7.9). Participants were asked to look at an image showing four possible places for placing a tree monitoring plot. The question asked *‘Which of the following plots are well placed to allow you to efficiently record tree monitoring data in the forest? Think about the number and size of trees you might want to observe, and how long it will take you to move between trees’*. Once a plot was selected the participants were asked to provide the reasoning behind their choice. This carried a maximum of 7 marks; 0-3 marks for plot choice, and 0-4 marks for the reasoning.

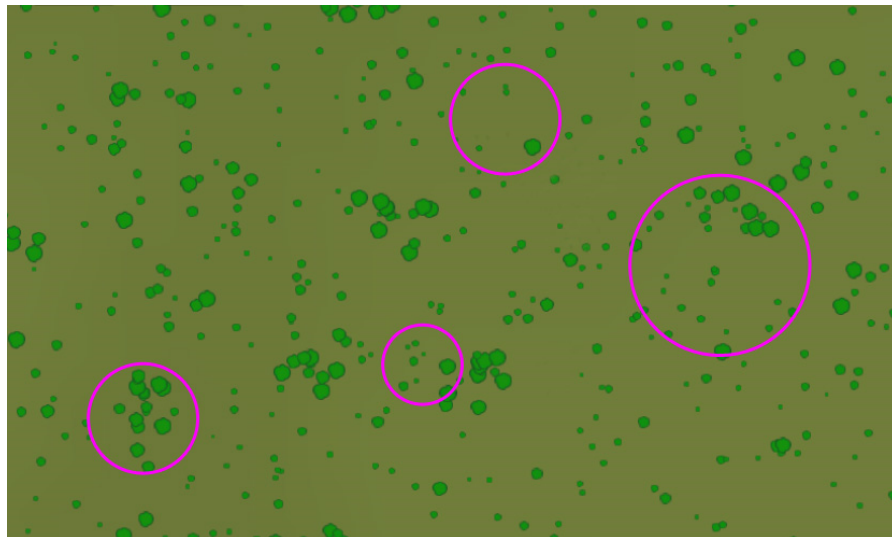


Figure 7.9 – Visual choice question

These questions were designed to test the participant’s knowledge acquisition on the learning outcome pre and post activity. This same test was provided as part of the follow up survey to establish the level of knowledge retention after a period of four weeks. See appendix C.2 for the full list of questions asked.

### 7.6.2 Perception on Flow Conditions

We used a modified version of the perception on Flow questionnaire developed for the GeoThermal World study. The modifications in the categories were again based on the sets of Flow statements developed by Fu et al., (2009) in their EGameFlow scale. Participants took the questionnaire directly after the activity while the feelings on the experience were still fresh.

On this occasion the questionnaire comprised of 27 individual questions collated under 9 category headings with 3 questions per category. Perceptions on Flow criteria for enjoyment were measured on a 5 point Likert scale; with (1) being strongly disagree, (5) being strongly agree, and (3) being neutral. In this case we removed the Social Interaction set of statements as we discovered from the *GeoThermal world* study that gaming was primarily a singular activity unless you have multiplayer networking in place which we did not.

In this study a Cronbach's alpha coefficient reported of .925 for the 27 items for the adapted EGameFlow scale. Showing that the scale has good internal consistency, comparing well to the Fu et al., (2009) EGameFlow alpha coefficient of .942 for their 42 items.

The seven specific Flow conditions were: 1) Challenge, 2) Goal Clarity, 3) Feedback, 4) Concentration, 5) Autonomy (control), 6) Immersion – Loss of self consciousness, and 7) Immersion - Loss of Time awareness. In the Geothermal World game there was only one Immersion category, and that combined the two Flow conditions of Loss of Self-consciousness and Loss of Time Awareness. As a result of the Geo study it was decided that, to gain a more accurate picture of Flow perceptions, we would more clearly define these two conditions and add more depth by separating them out into their own sections.

A decision was taken to replace the Social Interaction section as it was unrelated to Flow and the experience in both conditions essentially was single-player. Social Interaction was replaced with the category of Knowledge Improvement from the EGameFlow scale. The inclusion of the Knowledge Improvement perception questions would provide a basis against which we could compare the actual knowledge acquisition scores. This would allow us to discover if there was a correlation between what participants thought they had learnt and what they had in fact learnt. The ninth category was our addition of Enjoyment, which was useful for providing a quick overview of the participant's perception of the experience. This version of the amended EGameFlow survey can be seen in Appendix C.3.

### **7.6.3 Perceptions on Possum Control**

The perceptions on Possum control and practice were collected pre-activity gathering information that would help to form a baseline of the current perceptions of our study group. They were asked to agree/disagree with a range of statements based on past experience with possum control, the possum control situation locally and across New Zealand, and their perceptions of control practices. In total there were 22 statements across these topics that were measured on a 5 point Likert scale; with (1) being strongly disagree, (5) being strongly agree, and (3) being neutral.



For the follow up survey we narrowed the 22 statement down to the five most relevant statements chosen from the local and national situation questions. We also presented an additional nine statements, again on a 5 point Likert scale, asking for a level of agreement on statements beginning 'Since participating in the experiment...'. Both the pre and follow-up statement can be found in appendix C.4 and C.5.

## 7.7 Procedure

In keeping with the experimental design from the *GeoThermal World* study, each condition had three stages; 1) pre-activity measures, 2) the activity itself, and 3) post-activity measures. Ethics approval was received for the study prior to executing any data collection. On entering the room participants were asked to choose a workstation and help themselves to refreshments. Their attention was then drawn to a slide projection that provided an overview of the session.

The slide contained the following information:

*You may ask the researcher for help at any time*

**Purpose:**

*To investigate the effectiveness of interactive environments for learning and engaging with pest management and forest health in New Zealand.*

1. *Pre-activity questionnaire (approx 15 mins)*
2. *Pest Management activity (approx 15 mins)*
3. *Post activity questionnaire (approx 15 mins)*
4. *Follow-up questionnaire by email in 3 weeks*

*All recorded data is anonymous, participation is voluntary*

*Human ethical approval reference – HEC 2013/47/LR-PS*

This slide presented a condensed version of the online version full information sheet which was on welcome screen at each workstation. Once the information was reviewed the subjects clicked through to the consent form with the declaration of consent given electronically. Once this was done the participants were asked for contact details required for the follow-up survey.

### 7.7.1 Pre-activity

The pre-activity questionnaire collected demographics; age, gender and education level, familiarity with technology, and computer games. It then moved on to collect perceptions on possum management before the skills test on possum impacts on New Zealand tree species. Instructions for the test were as follows: Please answer the questions to the best of your ability. The researcher will be there to help if

needed. Please do not discuss the contents of this test with the other participants. Remember the test is entirely confidential and your peers cannot access your information.

On completion of this section the subjects were told to stop and notify the researcher that they had finished the pre-activity.

### 7.7.2 The Activity

- **ORA** – for this activity the subjects were asked to minimise the survey screen and enter their user ID into the activity login screen. They were then reminded that they could ask for help and their attention was drawn to the keyboard control print-out for navigation around the game world. Finally, they were asked to put on their headphones and left to complete the game activity at their own pace.
- **PME** – for this activity the subjects were asked to minimise the survey screen and enter their user ID into the activity login screen. They were reminded about asking for help and attention was drawn to the keyboard control print-out for navigation around the game world. The researcher then began to lead the activity through verbal instruction, and with the visual aid of a PowerPoint presentation. The group of participants were kept synchronised during the activities tasks by the pacing of the slides and the timings of the researcher. Those who finished a task quickly were free to explore the 3D world while waiting for others in the session to catch-up.

### 7.7.3 Post activity

Once the activity was completed the participants were asked to return to the online questionnaire, where they were presented with the Flow statements set out under nine category headings. The advisory for this survey read - *The purpose of this survey is to record your perception of the activity you have just undertaken. There are no right or wrong answers, your personal opinion is what matters the most. Please select the response which you feel most closely represents your view on each statement.*

The completion of the Flow survey led directly into the post-test knowledge exam. This was a repeat of the pre-test questions presented in a different order to reduce adverse practice effects (Newell & Rosenbloom, 1981), due to familiarisation.

The final section of the System Usability Scale (SUS) survey devised by Brooke, (1996) SUS: A “quick and dirty” usability scale, measured the usability of the pest management system presented in the PME and ORA conditions.



## 7.8 Results

The results will explore the data collected for the four dependant measures under test. We will look firstly at knowledge acquisition; exploring the pre and post scores, and then the level of knowledge retained after a 4 week break. We will then move on to look at the perception on Flow conditions between the two groups. We will further explore any connection between Knowledge scores and Flow, and finally we will finish with a review of perceptions on possum control, which will lead us into the discussion section.

### 7.8.1 Knowledge Acquisition

Figure 7.10 and 7.11 show a comparison of pre and post total mean scores for each condition. These descriptive results indicate an increase in knowledge acquired for both conditions of the study. It is clear from the figures that both activities had an impact on learning, with the largest difference seen in the short answer question results.

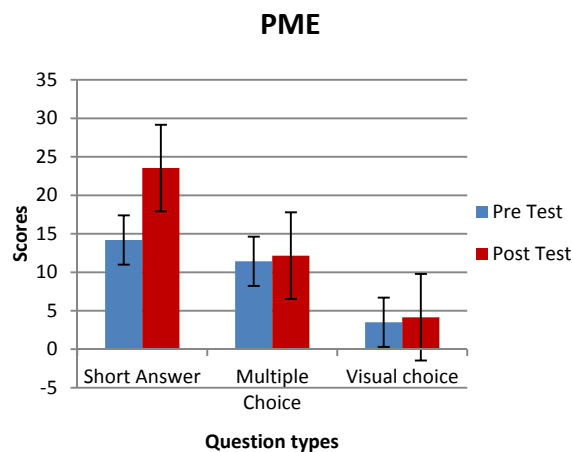


Figure 7.10 - PME Pre-Post test scores by question type

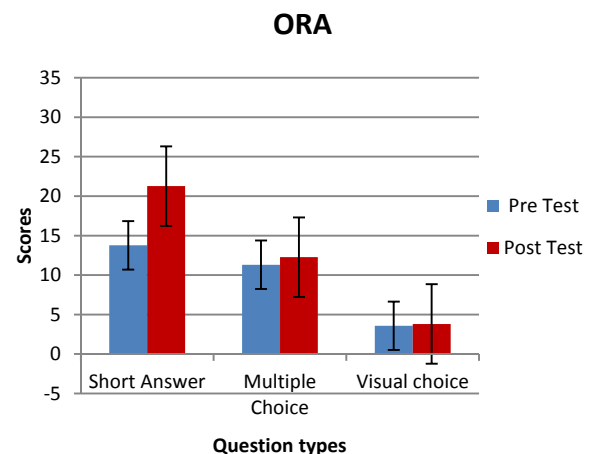


Figure 7.11 - ORA Pre-Post test scores by question type

Figure 7.12 below compares the totalled mean scores for the two conditions. The total mean score was an average calculated from the total scores for each the three question types. A delta score was then calculated using Hake's (1998) formula to provide the degree of change between pre and post levels. The average degree of change between pre and post activity was 22% for ORA and 27% for PME. The PME condition had achieved a higher mean score than the ORA condition both Pre and post. The total test scores were out of 70 marks.

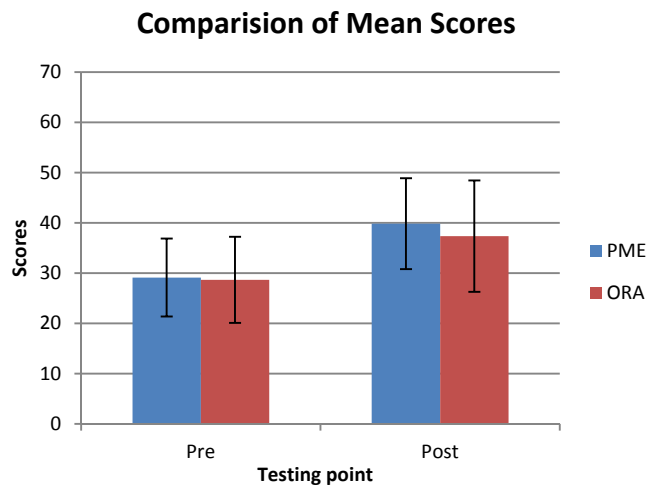


Figure 7.12 - comparison of pre/post totalled mean scores between conditions

#### 7.8.1.1 t-test

We then used the degree of change delta for the pre and post gains to run an Independent t-test. The test revealed that there was no statistically significant difference between ORA and PME with  $t(51) = -.979$ ,  $p = .332$ . The effect size,  $d$ , was computed to be 0.27, which is a small effect size. Table 7.2 shows the mean knowledge acquisition for both groups' conditions.

Table 7.2 - Mean knowledge acquisition per condition

	Group	N	Mean	Std. Deviation	Std. Error Mean
Gains	ORA	26	.222799	.1715435	.0336424
	PME	26	.268264	.1632278	.0320116

#### 7.8.1.2 Mixed ANOVA

A two-way mixed ANOVA was conducted to determine whether there were statistically significant differences in knowledge acquisition at three differing points in time between the two groups.

The follow-up knowledge exam had a 73% response rate with numbers of respondents evenly split between PME and ORA conditions. This meant we ran the ANOVA with a total of  $n = 19$  as opposed to an  $n = 26$  for the pre/post delta t-test analysis. We carried out the two-way mixed ANOVA on the raw scores for the pre/post and follow-up, to look for differences over time and between groups. Table 7.3 displays the mean scores for the two groups over the three testing times.

Table 7.3 - Descriptive statistics for the two groups scores over time.

	Group	Mean	Std. Deviation	N
Pre Total	ORA	30.06	7.471	18
	PME	30.42	7.508	19
	Total	30.24	7.388	37
Post Total	ORA	38.61	9.017	18
	PME	42.32	9.000	19
	Total	40.51	9.079	37
Follow-Up	ORA	35.28	9.170	18
	PME	32.16	13.238	19
	Total	33.68	11.395	37

There was one outlier in the data, as assessed by inspection of a box-plot for values greater than 1.5 box-lengths from the edge of the box. This outlier was removed from the analysis. Knowledge acquisition was normally distributed for all interventions at all time-points, as assessed by Shapiro-Wilk's test ( $p > .05$ ). There was homogeneity of variances, as assessed by Levene's test of homogeneity of variance ( $p > .05$ ). There was also homogeneity of covariance, as assessed by Box's M test of equality of covariance matrices ( $p = .099$ ).

Results of Mauchly's Test of Sphericity show that sphericity was violated ( $\chi^2(2) = 10.196$ ,  $p < .006$ ), therefore we adjusted results using a Greenhouse-Geisser correction ( $\epsilon = .794$ ). We found that there was a statistically significant interaction between the intervention and time on knowledge acquisition;  $F(1.588, 55.596) = 3.701$ ,  $p < .05$ , partial  $\eta^2 = .096$ . This means we found an overall difference somewhere between the factor of time and the knowledge acquired.

We then conducted a univariate test to explore this difference more deeply. We found no statistically significant difference in knowledge between ORA and PME conditions on the pre-test  $F(1, 35) = 0.22$ ,  $p = .883$ , Partial  $\eta^2 = .001$ , the post-test  $F(1, 35) = 1.563$ ,  $p = .219$ , Partial  $\eta^2 = .043$ , or the follow-up test  $F(1, 35) = .687$ ,  $p = .413$ , Partial  $\eta^2 = .019$ . But, there was a statistically significant effect of time on knowledge for both the ORA ( $F(2, 34) = 25.3$ ,  $p < .0005$ , Partial  $\eta^2 = .598$ ) and PME ( $F(1.42, 25.51) = 25.3$ ,  $p < .001$ , Partial  $\eta^2 = .497$ ) conditions. The PME condition had a Greenhouse-Geisser correction ( $\epsilon = .709$ ) applied to it, as Mauchly's test of sphericity was significant  $\chi^2(2) = 8.999$ ,  $p = .011$ .

Although there was no statistically significant difference between the groups, we did find that the difference between the scores for knowledge acquisition changed significantly over the three testing times for both the ORA and PME conditions.

A post hoc analysis with a Bonferroni adjustment revealed that:

- For the ORA condition, knowledge was statistically significantly higher in the post-test compared with the pre-test ( $M = 8.56$ ,  $SE = 1.17$  marks,  $p < .001$ ), significantly higher in the post than the follow-up test ( $M = 3.33$ ,  $SE = 1.13$  marks,  $p < .05$ ), and also significantly higher in the follow-up compared with the pre-test ( $M = 5.22$ ,  $SE = 1.33$  marks,  $p < .01$ ).  
Therefore we found the ORA group to have maintained a statistically significant difference between the pre-test and the follow-up test.
- For the PME condition knowledge was statistically significantly higher in the post-test compared with the pre-test ( $M = 11.90$ ,  $SE = 1.31$  marks,  $p < .001$ ), and significantly higher in the post-test compared with the follow-up ( $M = 10.16$ ,  $SE = 2.56$  marks,  $p < .005$ ). The PME group had no statistically significant difference between the follow-up test and the pre-test ( $M = 1.74$ ,  $SE = 2.47$  marks,  $p = 1$ ).

What we have discovered from the mixed ANOVA is a significant upward change from pre to post knowledge levels after both PME and ORA activities, and then a significant change in the other direction from post to follow-up levels. Those that undertook the PME activity returned to a knowledge level that was not significantly different from their pre-test levels of knowledge, but those who took the ORA activity proved to have a significant difference in their level of retained knowledge between pre and follow-up levels. Even though there was a difference found for ORA between pre and follow-up, no difference was found between the groups on their knowledge acquisition scores at the three testing points. Fig. 7.13 illustrates the changes over time of the averaged knowledge scores and displays the small but positive impacts of the different conditions on learning.

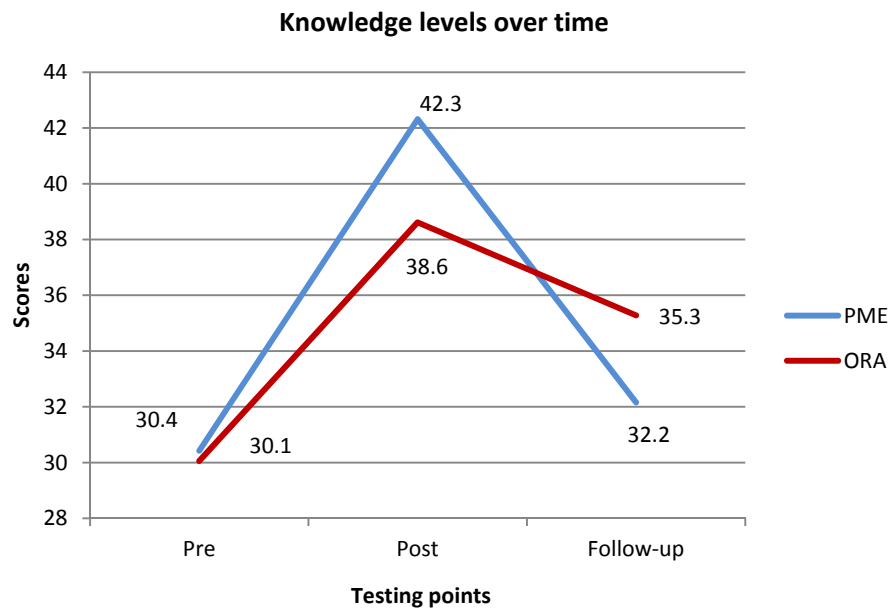


Figure 7.13 - Knowledge change over time

### 7.8.1.3 Summary

- PME had a higher pre/post mean score than ORA. The average degree of change, known as learning gain, between pre and post activity was 22% for ORA and 27% for PME.
- The t-test of the delta for learning gains, calculated for the pre/post only, found no significant difference between ORA and PME.
- The mixed ANOVA found no statistically significant difference between ORA and PME conditions when comparing the pre/post and follow-up scores.
- The mixed ANOVA did find that both ORA and PME had experienced a statistical difference in pre to post-test levels.
- Knowledge retention after 4 weeks was higher for ORA than PME. PME levels had returned to a level where no significant change could be detected from pre-activity levels, but ORA had retained a significant change upwards from pre-test levels.

## 7.8.2 Perception on Flow Conditions

### 7.8.2.1 Descriptive Results

Figure 7.14, shows the percentage of participants that indicated a positive response of Agree/Strongly Agree to the Likert scale statements measuring participant enjoyment on Flow conditions. If the measurement scale could accurately measure a Flow state then it could be supposed that scores of 100% positive responses would indicate the entering of a Flow state. Anything below only allows us to

measure the degree of Flow that the environments induced. In the PME simulation condition 50% of respondents gave a positive response in four out of the nine Flow condition categories, and of that 70% of respondents felt positive in three of those. In the ORA game 50% of respondents gave a positive response in seven out of the nine categories, and of that 70% of respondents felt positive in five of those. From this we see a trend indication that the ORA game elicited a higher percentage of positive participant reactions to Flow conditions.

The largest differences between the two groups were in the category of Feedback, with 82% of ORA respondents feeling positive about the level of feedback received on their actions, over 43% of those in the PME condition. The other notable category was Immersion-Time where 71% of those in ORA felt they had become immersed in the activity and lost awareness of time passing, compared to only 46% in the PME. The categories of Goal Clarity and Concentration in both PME and ORA conditions received 70% or more positive responses, but in these categories the PME condition was ahead of ORA. Although the differences were very small, with 2.5% of subjects more positive on Goal Clarity and 1.5% of subject more positive on Concentration, the trend is also borne out in favour of the ORA condition over the PME condition in the category of Enjoyment. Although it seems the majority from both conditions felt they had enjoyed the experience.

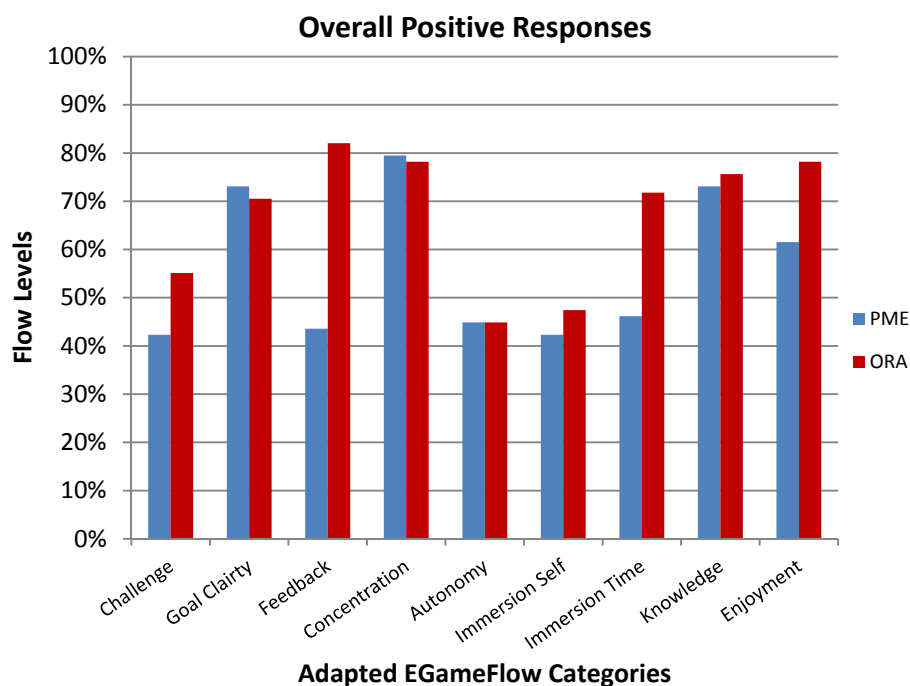


Figure 7.14 - Overall positive responses per category between the PME and ORA experience

A Mann-Whitney U (MWU) test was carried out between the ORA game and PME simulation, to establish if there was any significant difference between the experiences for participant enjoyment on the Flow criteria. This non-parametric test was chosen because we had ordinal data from our 5 point Likert scale and we were still dealing with a small sample size. Use of this test also allowed us to compare data between the previous *GeoThermal World* game study and the ORA game to establish if we had similar patterns.

Firstly, the 27 individual question scores were averaged into 9 headline categories and analysed for difference. The trends in the mean rank per category between the ORA and PME experience are displayed in Table 7.4 below.

Table 7.4 - The mean rank on participant enjoyment between ORA and PME

	Group	N	Mean Rank	Sum of Ranks
<b>Challenge</b>	<b>ORA</b>	26	<b>29.52</b>	767.50
<b>Delta</b>	PME	26	23.48	610.50
<b>Goal Clarity</b>	ORA	26	26.08	678.00
<b>Delta</b>	PME	26	26.92	700.00
<b>Feedback</b>	<b>ORA</b>	26	<b>33.69</b>	876.00
<b>Delta</b>	PME	26	19.31	502.00
<b>Concentration</b>	ORA	26	24.37	633.50
<b>Delta</b>	<b>PME</b>	26	<b>28.63</b>	744.50
<b>Autonomy</b>	ORA	26	26.17	680.50
<b>Delta</b>	PME	26	26.83	697.50
<b>Immersion- Self</b>	<b>ORA</b>	26	<b>27.92</b>	726.00
<b>Delta</b>	PME	26	25.08	652.00
<b>Immersion- Time</b>	<b>ORA</b>	26	<b>30.60</b>	795.50
<b>Delta</b>	PME	26	22.40	582.50
<b>Knowledge</b>	ORA	26	25.67	667.50
<b>Delta</b>	<b>PME</b>	26	<b>27.33</b>	710.50
<b>Enjoyment</b>	<b>ORA</b>	26	<b>29.15</b>	758.00
<b>Delta</b>	PME	26	23.85	620.00

The mean ranks reflect the descriptive trends, in that Feedback and Immersion-Time rank highest for the Ora condition. Challenge and Enjoyment rank at 29 for Ora, compared to 23 for PME, for positive perception scores.

### 7.8.2.2 Statistical Analysis of Results

The MWU test results for statistical significance of difference are shown in Table 7.5. A statistically significant difference was found in the categories of 3. Feedback, and 7. Immersion – Loss of time awareness. The mean rank of the ORA game was higher than the mean rank of the PME simulation, therefore the Ora game achieved a higher Flow criteria for participant perception on Feedback and Immersion - Loss of time awareness, than PME.

Table 7.5 - MWU Results of Flow outcomes per category

<b>1. Challenge</b>	
No statistically significant difference	U = 259.5, $p > .05$ . (computed $p = .143$ )
<b>2. Goal Clarity</b>	
No statistically significant difference	U = 327, $p > .05$ . (computed $p = .838$ )
<b>3. Feedback</b>	
<b>High statistically significant difference</b>	U = 151, $p < .001$ (computed $p = 0.0005$ )
<b>4. Concentration</b>	
No statistically significant difference	U = 282.5, $p > .05$ . (computed $p = .277$ )
<b>5. Autonomy</b>	
No statistically significant difference	U = 329.5, $p > .05$ . (computed $p = .875$ )
<b>6. Immersion - Loss of self-consciousness</b>	
No statistically significant difference	U = 301, $p > .05$ . (computed $p = .494$ )
<b>7. Immersion – Loss of time awareness</b>	
<b>A statistically significant difference</b>	U = 231.5, $p < .05$ (computed $p = 0.049$ )
<b>8. Knowledge</b>	
No statistically significant difference	U = 316.5, $p > .05$ . (computed $p = .686$ )
<b>9. Enjoyment</b>	
No statistically significant difference	U = 269, $p > .05$ . (computed $p = .180$ )



Table 7.6 displays the individual questions from which scores were used to calculate the delta for the categories. The ones displayed here are for the significant categories of Feedback, and Immersion-Time. Unlike the GeoThermal World study none of the other categories of individual questions, when accessed via the MWU test, displayed any statistically significant differences.

Table 7.6 - Results of the statistically significant Flow category by individual question

<b>3. Feedback</b>	
Q1 - During the activity, I received feedback on my progress	<b>Reject the Null Hypothesis</b> U = 157.5, $p < .005$ (computed $p = 0.0005$ , which is a highly statistically significant difference) Mean rank of ORA is higher than PME
Q2 - During the activity, I received immediate feedback on my actions	<b>Reject the Null Hypothesis</b> U = 232.5, $p < .05$ (computed $p = 0.034$ ) Mean rank of ORA is higher than PME
Q3 - During the activity, I received immediate information on my success (or failure) of the goals	<b>Reject the Null Hypothesis</b> U = 189.5, $p < .005$ (computed $p = 0.003$ , which is a highly statistically significant difference) Mean rank of ORA is higher than PME
<b>6. Immersion Loss of time awareness</b>	
Q1 - I forget about time passing while involved in the tasks	Retain the Null Hypothesis U = 293.5, $p > .05$ . (computed $p = 0.387$ ) Mean rank of ORA is higher than PME
Q2 - I temporarily forget any worries about everyday life while involved in the tasks	Retain the Null Hypothesis U = 266, $p > .05$ . (computed $p = 0.141$ ) Mean rank of ORA is higher than PME
Q3 - I become unaware of my surroundings while involved in the activity.	<b>Reject the Null Hypothesis</b> U = 234.5, $p < .05$ (computed $p = 0.045$ ) Mean rank of ORA is higher than PME

In Fig. 7.15 and 7.16 we show a comparison of the totalled scores for the two significant categories, displayed as individual questions results.

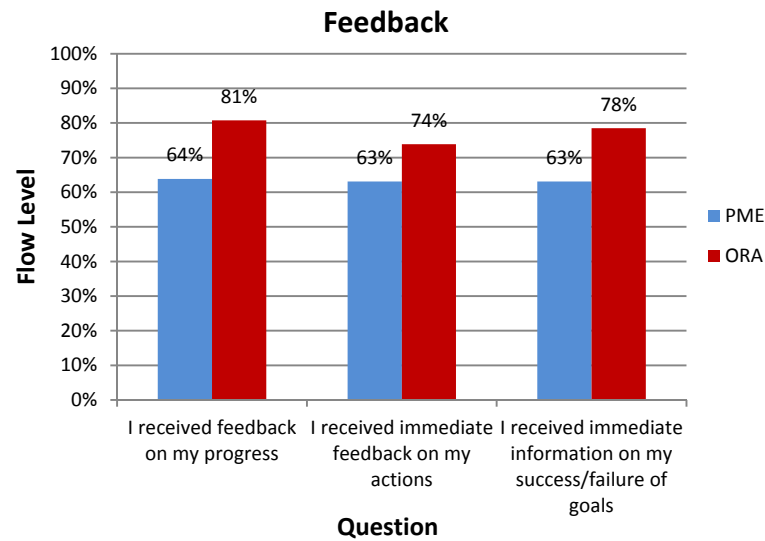


Figure 7.15- Percentage of total scores per individual question.

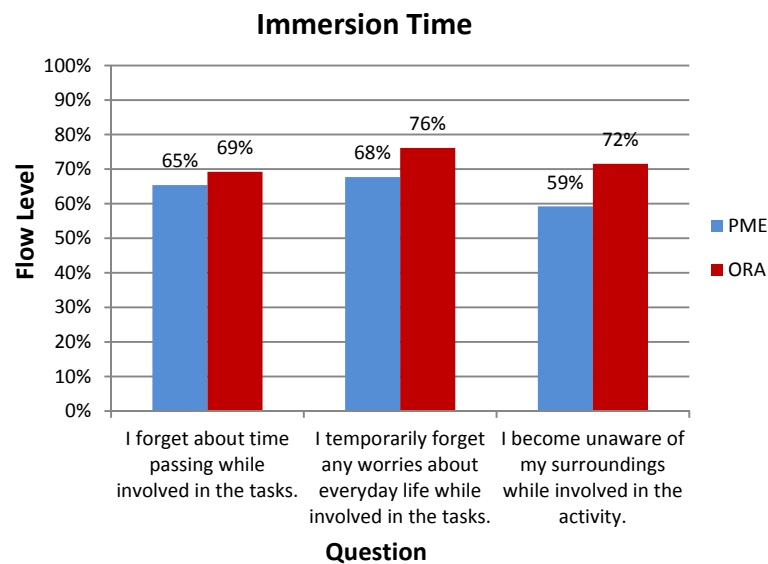


Figure 7.16 - Percentage of total scores per individual question.

By looking at the results in this way we begin to get a feel for the nature of the differences between the two groups. In Feedback the differences are across the board, with those involved in the ORA game condition having higher total scores for in-game feedback. Most notable is the difference for question 1 ‘feedback on progress’ with 81%, as opposed to the 64% for PME. For Immersion - Loss of time awareness, total scores for ORA reached 72%, as opposed to 59% in PME. This was in response to question 3, assessing agreement that they ‘became unaware of their surrounding’ while they engaged with the game’s activities.

### 7.8.2.3 Summary

- Descriptive trends show participants who played ORA left with a more positive perception of the experience than PME participants. In ORA 70% of players responded positively in 5 out of the 9 categories, compared to a 70% positive response in 3 out of the 9 categories for PME.
- Analysis of the mean ranked scores show the ORA experience generated higher positive perceptions scores on 5 out of the 9 Flow categories. PME ranked higher in two which were for Concentration, and Knowledge. Both groups ranked equal for perceptions on Autonomy.
- The Mann-Whitney U test showed two categories to have a statistically significant difference between the two groups. These were in the categories of Feedback and Immersion – Loss of time awareness, with the ORA game having a higher mean rank in both instances. No other differences were found.
- An MWU analysis of difference, when ran on the individual questions in each category, showed that there were statistical differences found only for Feedback, and Loss of time awareness.

### 7.8.3 Perceptions on Possum Control

After collecting the initial set of perception of possum impacts in the pre-activity survey we asked our participants to complete a follow-up survey four weeks later. Of the fifty two original participants we had thirty eight respondents, split even between the groups. We conducted this analysis to measure any degree of change from the pre-activity state. This was done to provide a measure of impact that either or both activities had on longer-term perceptions towards possum control. We were also looking to see if there was any difference between the groups, which could tell us if either of the conditions had more of an impact than the other.

We presented the five most relevant perception statements seen in Table 7.7. These questions were selected from a range of statements from the 'Perceptions of Possum Control' section of the Pre-activity survey. The statements were presented on a 5 point Likert scale, with answers ranging between 1) for strong disagree, to 5) for Strongly agree. (The a copy of the online survey can be seen in appendix C.5) From the outcome of these five questions a pre and follow-up average score was created. A higher score represented a higher level of concern or understanding of the topic of possum control/management.

Table 7.7 - Possum Perceptions Statements

Q1.	In NZ possums are a problem
Q2.	Possums are only an issue for farmers
Q3.	The Department of Conservation has enough resources to completely remove possums
Q4.	The possum problem in NZ is complex and possum management is difficult
Q5.	Possums are only a problem because they eat NZ's native plants.

Figures 7.17 offers a visualisation of the degree of change, as calculated from the five questions in table 7.7, from pre to follow-up levels for the thirty eight respondents. The trend shows that there is a positive degree of change in the participant's perceptions from the pre-activity level. The average perception score was the mean of questions 1 to 5 after the negatively worded questions (Q2, 3, 4 and 5 in the pre Questions, and Q2, 3 and 5 in the post questions) had been recoded.

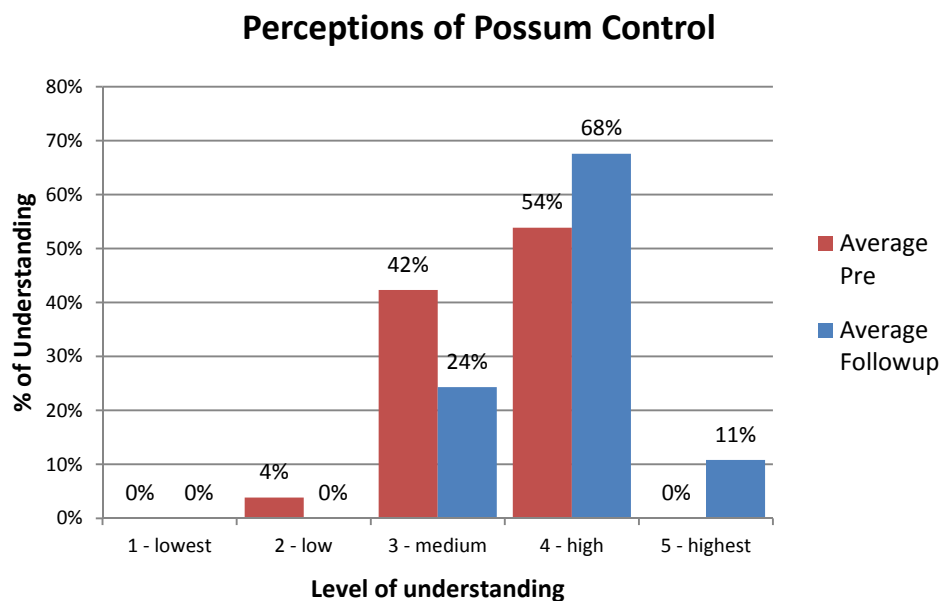


Figure 7.17 - Range and levels of understanding and concern about possum control

We chose the Wilcoxon signed ranks test to conduct a repeated measures analysis. This allowed us to examine if there was a statistically significant change in perceptions on Possum Control from time 1 to time 2. We chose this non-parametric test as we had ordinal data from our 5 point Likert scale and we were dealing with a small sample size (38).

Firstly we carried out the test collectively with all 38 participants regardless of group, to see if there was a change between time 1 and 2. We found a statistically significant difference between pre-activity perceptions and follow-up,  $z = -1.959$ ,  $p = .05$ . The positive ranks were higher than the negative ranks, meaning follow-up perceptions had a higher average perception change from pre-activity levels.

We then carried out the same test on the ORA group, which showed that there was no statistically significant difference between pre-activity perceptions and follow-up,  $z = -1.87$ ,  $p > .05$  (computed  $p = .235$ ). This was the same outcome for the PME group where the test showed that there was also no statistically significant difference between pre and follow-up perceptions,  $z = -1.591$ ,  $p > .05$  (computed  $p = .111$ ).

Collectively we found a change showing that taking part in the activity had a positive impact on perceptions, but when we split the sample into their groups and ran the test again we couldn't find a significant degree of change from time 1 to time 2 based on group. This may have been due to the smaller sample size as individual groups.

A Mann-Whitney U test was carried out to look for difference between ORA and PME on the follow-up average perception change. The test showed that there was no statistically significant difference between ORA and PME,  $U = 142.000$ ,  $p > .05$  (computed  $p = .253$ ). Results of the mean ranks are shown in table 7.8.

Table 7.8 - Mean rank comparing average follow-up perception scores

	Group	N	Mean Rank	Sum of Ranks
Follow-up Ave Perception	ORA	19	21.53	409.00
	PME	19	17.47	332.00
	Total	38		

### 7.8.3.1 Post Participation Impacts

Alongside judging the perception change on the domain topic for a pre to post change, we also wanted to gauge what level of personal impact taking part in the experiment had had, and if there were any differences between the groups. We devised a series of questions outlined in Table 7.9. which were presented as statements. Participants were asked to indicate on a 5 point Likert scale their level of agreement (1 = Strongly Disagree, 5 = Strongly Agree, see Appendix C.5 for the Follow-up Survey). This gave us some data as to the whether either condition had had a personal impact on the subjects perceptions.

Table 7.9 - Personal impact statements

Since participating in the experiment:-	
Q1	I am more aware of the impact possums can have on native forests
Q2	I care more about forest health
Q3	I feel more informed about possum impacts on native forests
Q4	I would like to know more about how to control possums in new Zealand
Q5	I think I would notice possum browse on trees more than I did before
Q6	I would look for possum browse while out in the countryside
Q7	I feel I am more aware of the impacts of pest species in New Zealand forests
Q8	I think my interest in possum impacts on NZ forests has increased after participating.
Q9	I have researched the topic

Figure 7.18 shows the positive responses calculated from the percentage of those who had responded with agree or strongly agree.

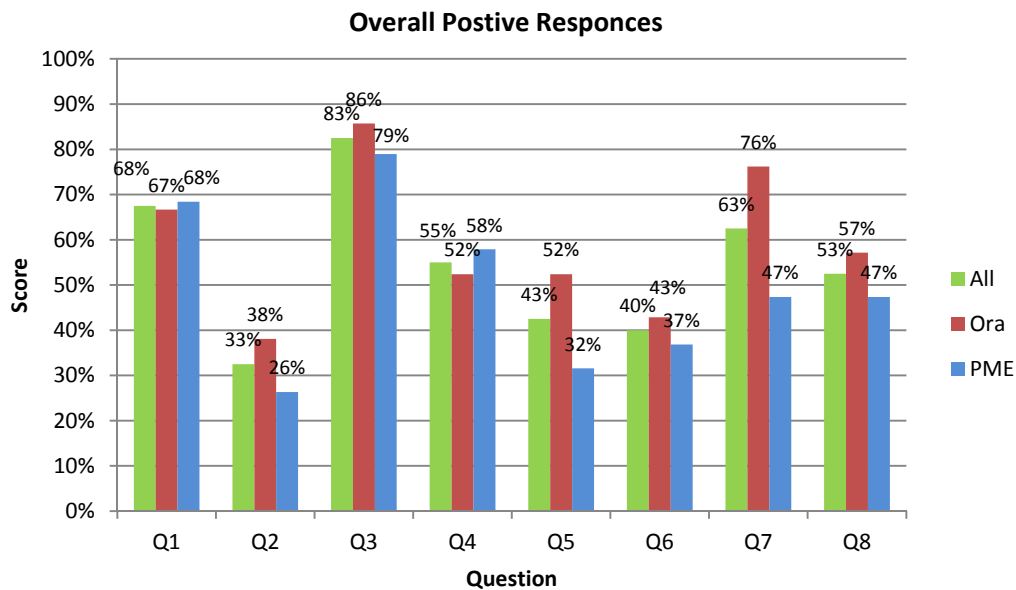


Figure 7.18 - A comparison of overall positive responses to the personal impact statements

The most positive responses gathered were for question 3 – I feel more informed about possum impacts on native forests, with ORA having a positive response of 86% to PME at 76%. The least amount of positive results was for question 2 - I care more about forest health, where only 38% for ORA and 26% for PME felt positive. The largest difference between the groups was in response to question 7 - I feel I am more aware of the impacts of pest species in New Zealand forests, with a 29% difference between ORA and PME subjects. The other noticeable difference was on question 5 - I think I would notice possum browse on trees more than I did before, where there was a 20% difference between ORA and PME. When asked in question 9 whether they had researched the topic post participation only 8% indicated that they had. Of that figure the PME group was at 11% and the ORA group at 5%.

We ran a Mann-Whitney U test to compare the two groups to establish if we had any statistical differences between the groups on the individual questions, but no significant differences were found.

### 7.8.3.2 Summary

- The descriptive data showed a positive change in the overall level of understanding and concern about possum control from pre-activity levels to follow-up levels.
- When we ran a Wilcoxon signed-rank test we found a collective change between time 1 and 2 when sampling all participants, but when split into groups no significant change was found. Results of a MWU between subjects tested also provided no evidence that there was a difference between the groups on the average perception change.
- When assessing the personal impact statements post participation we found some descriptive differences between ORA and PME, but a MWU test found nothing of significance.

Although there was an overall positive change in perceptions on possum control and management for participants from time 1 to time 2, we could find no evidence that the group they were part of had any impact. Taking part in the experiment had a positive impact but the group they were placed within was not a factor.

#### **7.8.4 Correlations**

From the three data sets collected we wanted to discover what, if any, relationships there were between the sets. To do this we ran a Spearman's rank-order test, which is more suitable for combined continuous and ordinal data correlation. We chose to do this as we had continuous data from our knowledge scores and ordinal data from the Flow and possum perceptions Likert scale scores. Preliminary analyses were performed to ensure no violation of the assumptions of normality, linearity and homoscedasticity. For correlations that returned significant results we calculated the shared variance to indicate the level of association. We ran the tests on each of our two conditions, ORA and PME, and looked for patterns and differences in the results.

##### **7.8.4.1 Knowledge acquisition**

Firstly we wanted to know if there an association between knowledge acquisition levels and positive scores on Flow. We were particularly interested in associations between the follow-up scores and the 7 Flow conditions, as we had found differences between ORA and PME levels of knowledge retention.

Alongside the 7 Flow conditions outlined by Csikszentmihalyi (1990), we included the additional categories of Enjoyment, Knowledge and an averaged flow score. We ran these against the knowledge acquisition scores of the delta for learning gain on pre-post, pre-follow up and against the total score of pre, post and follow-up. Results of the Spearman's rank-order test found a medium positive correlation between post-total and Autonomy (control) for ORA, with a shared variance of 20% [ $r=.457$ ,  $n=25$ ,  $p<.05$ ]. However, this was the only significant result found for both ORA and PME. We could find no evidence of association for Flow and level of knowledge retention from the follow-up seen in the ORA group or in the PME group.

##### **7.8.4.2 Flow perceptions**

Next we wanted to know if the two known Flow categories of Knowledge and Enjoyment had a positive correlation with the seven Flow categories. Table 7.10 displays a matrix of the significant results and their calculated shared variance. Knowledge in this case describes subject perception of their knowledge



improvement and is taken from the EGameFlow questions (Fu et al., 2009); it is not a knowledge score from testing. The results are shown for the two groups and significant values are shaded. Where a significant value was found in one group but not the other the non-significant results are displayed alongside. Blank sections mean no significance was found in either group.

Table 7.10 - Spearman's rank-order correlations between measures of Flow

Measures	Knowledge		Enjoyment	
	ORA	PME	ORA	PME
<b>Challenge</b>			.482* a. sv 23%	.554** b. <b>sv 30%</b>
<b>Goal Clarity</b>	.408* a. sv 16%	.343 b. sv 12%	.294 a. sv 8%	.404* b. sv 16%
<b>Feedback</b>			.502** a. sv 25%	.385 b. sv 14%
<b>Concentration</b>			.120 a. sv 1%	.388* b. sv 15%
<b>Autonomy (control)</b>	.344 a. sv 11%	.586** b. <b>sv 34%</b>	.600** a. <b>sv 36%</b>	.553** b. <b>sv 30%</b>
<b>Immersion _ Self</b>	.494* a. sv 24%	.403* b. sv 16%	.737** a. <b>sv 54%</b>	.626** b. <b>sv 39%</b>
<b>Immersion _ Time</b>			.584** a. <b>sv 34%</b>	.446* b. sv 19%

N=26 ORA N=26 PME

\*. Correlation is significant at the 0.05 level (2-tailed).

\*\*. Correlation is significant at the 0.01 level (2-tailed).

a. Group = ORA. b. Group = PME

sv = shared variance

As can be seen, perception of knowledge is not strongly associated with the categories of Flow for ORA or PME. It is notable that for PME, there appears to be a strong positive association between perceived knowledge level and perception of autonomy, with a sv of 34%. For enjoyment however, we do find a number of positive associations between Flow perceptions. Of the 7 flow categories 5 of those show a medium to large association for ORA, with 3 of the 5 showing 30% or more shared variance. For PME 6 out of 7 display an association, with 3 displaying 30% shared variance or more. The most strongly associated category for both ORA and PME is with Immersion - Loss of Sense of Self. PME shows a 34% shared variance but ORA is higher at 54%.

As we found a number of significant correlations between Flow, Knowledge and Enjoyment it was wise to verify if there was any relationship between levels of Enjoyment and Knowledge Improvement. The

results of this are shown in table 7.11, where a medium to large relationship is found for both groups, with the stronger association seen for PME.

Table 7.11 - Spearman's rank-order correlations

Measures	Knowledge	
	ORA	PME
Enjoyment	.475* a. sv 22%	.648* a. sv 42%

N=26 ORA N=26 PME

\*. Correlation is significant at the 0.05 level (2-tailed).

\*\*. Correlation is significant at the 0.01 level (2-tailed).

a. Group = ORA. b. Group = PME

sv = shared variance

#### 7.8.4.3 Possum perceptions

Finally we looked for patterns of association between knowledge acquisition, Flow and perceptions on possum control. Results of the Spearman's test show some degree of association between positive levels of perception on possum control and the Pre-test Total scores. The associations were only found in the PME condition and they ranged between medium to large, but the shared variance indicates only 20% to 26% of the subjects would display this association, as can be seen in table 7.12. We can't state that having high level of awareness and/or understanding of the topic of possum control has an impact on the pre-test knowledge, although there is small indication of influence.

Table 7.12 - Spearman's rank-order correlations between measures of possum control perception and pre-test scores

Measures	Av Full Pre Perception		Ave Pre Perception		Ave Follow-up Perception	
	ORA	PME	ORA	PME	ORA	PME
Pre-test Total score	.277 a. sv 8%	.453* b. sv 20%	.395 a. sv 15%	.511** b. sv 26%	.290 a. sv 8%	.511* b. sv 26%
	N=25	N=26	N=18	N=19	N=18	N=19

\*. Correlation is significant at the 0.05 level (2-tailed).

\*\*. Correlation is significant at the 0.01 level (2-tailed).

a. Group = ORA. b. Group = PME

sv = shared variance

When we looked at the relationship between the post participation impacts from the personal impact survey data, there was only one correlation which showed a large negative correlation between high

post-total scores and lower post-participation impact averages in the 4 week follow-up survey. This was only found in the ORA condition with a shared variance of 25% [ $r = -.509$ ,  $n=18$ ,  $p<.05$ ]. No other correlations were found for either group between possum perception levels and knowledge scores at any of the testing points.

It was a similar picture for the correlation between Flow and levels possum perceptions. For ORA and PME we found a small negative correlation between the high average pre-perceptions and low Immersion – loss of time perceptions. For ORA there was a shared variance of 15% [ $r = -.395$ ,  $n=25$ ,  $p<.05$ ], and for PME a shared variance of 15% [ $r = -.391$ ,  $n=26$ ,  $p<.0548$ ]. Other than these two small associations we found nothing to support a relationship.

#### 7.8.4.4 Summary

- Between the five types of test scores and the nine Flow categories we found no significant correlations, with the exception of a medium positive correlation between Autonomy and post-total test scores, but for the ORA group only.
- We found that there were limited correlations between the level of perceived knowledge and the seven core Flow categories. For ORA we found a medium level association with Goal Clarity, and for PME a strong association with Autonomy. Both ORA and PME showed a medium correlation with Immersion – Loss of self-consciousness.
- Between Flow and Enjoyment we found high levels of association across the seven Flow categories for both PME and ORA, with ORA displaying higher levels of shared variance.
- We found little evidence that higher levels of possum perceptions were associated with high knowledge scores. We did find a small level of association for the PME group between pre-average perceptions and Pre-test total scores.
- We found a strong association between perceived Enjoyment and Knowledge Improvement.
- We found no evidence that high flow perceptions and high possum perceptions had any relationship.

## 7.9 Discussion

Our findings show that in terms of learning, both groups experienced a significant increase in knowledge acquisition from pre-test to post-test levels. No statistical difference was found between ORA and PME at any of the pre, post and follow-up testing points. When knowledge retention was assessed post-study four weeks later, we found the ORA group still retained a statistically significant difference from their

pre-test levels. Whereas the PME group had returned to a level that was no longer significantly different from their pre-test levels.

We propose that the lack of statistical difference between the two groups in their immediate post-activity test levels could be attributed to the shared learning objectives (LOs) and user interface functions. We also had a well-educated set of subjects across both groups, who would be familiar with learning environments.

By comparison, the ORA group participants were engaged in a non-traditional style of learning in the form of LO's delivered via gameplay. Although they had the same set of learning tasks, they had to place additional cognitive resources into a self-directed discovery approach. This self-directed learning, guided by the SPP gameplay approach, is a possible explanation for the greater levels of knowledge retention seen in the follow-up scores of the ORA group when measured again after four weeks. Another possibility is that the in-game system of guided discovery delivered by the tutorial mode of the NPC Liana, and coupled with a deeper level of written instruction in the game's journal, provided a better cognitive resource for contextualising the learning problem than did the tutor-led PME simulation. Edmondson, et al., (2012) in their study found that 'meta-analytic results show that self-directed learning is significantly and positively related to academic performance'. The self-directed learning approach is associated within the Ora design with it's mapping of the intrinsic motivations. These motivations in turn support self-determined behaviour (Ryan & Deci, 2000) and when 'behaviour is self-determined, [it is] driven by their own volition rather than external forces' (Garris et al., 2002).

Our results show that both PME and ORA environments were effective for increasing immediate post-activity subject knowledge, and the ORA environment appeared more effective in aiding long-term knowledge retention. Bloomfield, Roberts, & While's, (2010) study with nursing students, where they explored computer-assisted learning versus conventional teaching methods, found 'knowledge scores increased significantly from baseline in both groups and no significant differences were detected between the scores of the two groups'. Similar with our study, Bloomfield et al. also found significant differences after an eight week follow-up, in favour of the group who used the self-directed computer-assisted learning module when compared to tutor-led sessions in a clinical skills room.

The primary reasons for surveying Flow characteristics is as a measure of the effectiveness of the SPP design approach. The SPP approach applies skilled performance (Fitts & Posner, 1967) (Bradshaw, 2010)

and motivational principles (Deci & Ryan, 1985) (A. H. Maslow, 1943) as its basis. As was argued in chapter 3 section 3.1.2, skilled performance shares many characteristics with those that describe a Flow state. Both the ORA and PME activities were designed to be as similar as possible, with the intention of minimising confounding variables. This allowed for a more precise interpretation of the results, in terms of the differences between the self-directed gameplay design of ORA and the tutor-led process of PME. This provided us with defined boundaries within which to understand the differences between our groups.

Although adapted EGameFlow scores showed that a Flow state, as described by Csikszentmihalyi, *p48-74* (1990) was not reached by either group, the ORA participants experienced more of the qualities that combine to elicit a Flow state than did the PME participants. The descriptive trends showed that participants who played the ORA game left with a more positive perception of the experience than the PME participants. These trends were reinforced as analysis of the Mann-Whitney U (MWU) mean ranks showed ORA ranking higher in 5 out of the 9 Flow categories compared to PME. The results of the MWU test found statistically significant differences between ORA and PME in the categories of Feedback and Immersion – loss of time awareness, with ORA having the higher mean rank in both instances.

In response to these results we suggest that the higher level of positive perception of the Flow conditions found with ORA were most likely a result of the self-directed gameplay delivery of the learning objectives. We were unsurprised that there was no difference between the groups for the first category of Flow, which is Challenge; even though ORA did have the higher mean rank score, as both ORA and PME shared the same learning objectives. However, we did find a difference in the last category of Flow, which is Immersion - loss of time awareness; where participants felt more immersed and became less aware of their surroundings and time passing. More significant was the difference in Feedback, with the ORA group feeling they had much more positive levels of feedback. The gameflow was specifically designed to deliver a range of feedback, which was teamed with a reward system, and where in some cases the reward was the feedback.

The Comparison principle (Bradshaw, 2007) of the SPD and SPP process is one of the four core principles defined from Fitts & Posner's, (1967) work on producing a Skilled Performance; where each 'act of the player is dependant upon comparison of what they think is desired, either through feedback (external stimuli) or comparison of progress towards a goal'. The feedback elements of the ORA gameplay are

built on this concept and provide a positive reinforcement loop which was not present in the tutor-led PME session.

Alternatively, we could for the moment set aside ORA's gameplay as the factor of difference, and consider the flaws with the PME task that disrupted perceptions of Flow. There are the possibilities that; the participants had to keep looking away from their workstations with the PME activity to pay attention to the information the tutor was presenting, which disconnected them from the PME world, and that they also progressed at a pace set by the slowest participant in that session. This could have invited boredom for the capable and anxiety for the less able. Therefore, it is possible that the results we found were learning-focused gameplay combined with the limitations of tutor-led sessions that together resulted in disruption in the generation of a Flow state. However, there is no evidence from the participants themselves to support this supposition.

We also collected perceptions on possum control and management to establish if taking part in the pest management activity could create a perception change. Initial analysis found that the majority of participants already had a medium to high level of understanding and concern for possum control issues, therefore we did not expect to find any significant change. However, a Wilcoxon signed-rank test ran with all 52 participants found a significant change between time 1 and 2. However, when split, into the groups no change was detected. A MWU test also found no differences between the two groups. Analysis of the personal impact statements at the post study 4 week follow-up point, which led with the phrase 'since participating in the activity I have...' found some descriptive differences between ORA and PME. However, a MWU test found nothing significant, although the ORA participants generally showed a more of a positive response than those of the PME.

Therefore, we found that taking part in the study had a positive impact on perceptions of possum control and understanding but that neither group environment, ORA or PME, provided an advantage in this. To gain a deeper understanding of the impact both digital experiences on possum perception, another study comparing the environments to the other available options should be conducted.

There are other fields of study, particularly in health related behaviour change, that find games and simulation to have a positive impact on behaviour change. Baranowski, et al., (2008) review twenty five such games and find 'playing most of these behaviour-change video games led to a broad spectrum of desirable outcomes from knowledge increases, to attitude changes, behaviour changes, and other

health-related changes.’ This is supported in studies of perceived decision making in marketing students (Wellington & Hutchinson, 2010) and on passenger safety in aircraft evacuations (Chittaro, 2012).

Finally, we ran a series of correlations using a Spearman’s rank-order test. We chose Spearman’s over Pearson’s as we had both continuous and ordinal data and Pearson’s is more suitable for continuous data. Firstly we looked for a relationship between knowledge acquisition and Flow. We were interested to know if there would be a link between the adapted EGameFlow categories of perceived Knowledge Improvement and the actual knowledge scores. This could provide insights into a link between perception of learning and knowledge acquisition, but no relationship was found.

We then turned to analysis of the Flow categories with the knowledge scores and learning gain deltas but again found no connections. However, we did find one exception to this, with the ORA group displaying a medium positive correlation between levels of perceived autonomy and their total-post test scores. We consider this unusual, as the perceptions on autonomy were almost identical for the two groups, with only a 0.1 degree difference between them. The main difference to be found was lower average post-total score for ORA at 37.3, compared to 39.8 for PME. Although the result was noteworthy, providing a medium level relationship with a shared variance of 20%, it is unlikely to indicate a wider trend.

Once Knowledge acquisition was assessed we wanted to take a look at the connections between the adapted EGameFlow questionnaire category of Knowledge Improvement and the Enjoyment baseline, against the seven core Flow categories. Fu's et al., (2009) reasoning for including Knowledge Improvement within the EGameFlow questionnaire was that the ‘factor of knowledge improvement replaced the factor of player skills in the concept of GameFlow by Sweetser and Wyeth, (2005) to better suit the goals of e-learning game development’. So we wished to explore if the inclusion of this category was helpful and relatable to Flow and gameplay heuristics as suggested. Our findings showed a small number of significant correlations between perceived Knowledge Improvement and the seven Flow categories. These were between; Goal Clarity for ORA, Autonomy for PME, and Immersion - Loss of self-consciousness for both ORA and PME. As outlined by Fitts & Posner, (1967) having clear goals is a key component in developing a Skilled Performance, and is a feature of the SPP approach. The learning objectives of ORA were delivered using the SPP so it is logical that we find this correlation for ORA and not PME. It is a little more difficult to interpret the positive association for the PME group between

Knowledge Improvement and Autonomy. Autonomy levels were almost identical for both groups but only PME was significant, where there was a considerable difference in the shared variance, with PME at 34% compared to ORA at just 11%. The most likely explanation for this is perhaps due to PME having the higher rating on perception of Knowledge Improvement than ORA; a rating that also reflected the higher post-activity knowledge score of PME.

Both groups also showed a significant association between their perceptions of Knowledge Improvement and Immersion - Loss of self-consciousness. Loss of self-consciousness is described by Csikszentmihalyi, (1990) as 'concern for the self disappears, yet, paradoxically the sense of self emerges stronger after the flow experience is over'. Although we only found a medium level relationship it does lend support to an indicative link between perceptions of participant's knowledge improvement and their immersion in the activity. These findings add weight to the inclusion and continued use of the Knowledge Improvement category in the EGameFlow questionnaire, and hints at a positive link between autonomy, clear goals and immersion with perception of knowledge, but it is beyond the scope of this study to provide a more definitive answer.

The category of Enjoyment was added to the questionnaire as a baseline measure. The addition provides a clarifying dimension to the other Flow categories, which both Sweetser & Wyeth, (2005) and Fu et al., (2009) argue evaluates player enjoyment. If this is the case then we would expect to find that high levels of Enjoyment perceptions positively correlate with the other Flow categories. Csikszentmihalyi, p49 (1990) states that 'the combination of all these elements causes a sense of deep enjoyment...'. Our analysis supports this as we found high levels of association across the seven Flow categories for both ORA and PME. PME had positive correlations in all categories but Feedback, and ORA showed positive correlations between all but Goal Clarity and Concentration. Although ORA only had five correlations compared to PME's six, the levels of shared variance for ORA were higher overall, so we saw a stronger effect for the ORA group. These higher levels in ORA could be the gameplay design effects introduced by the SPP approach. These findings are consistent with the correlation results found with the Game condition of the *GeoThermal World* study,<sup>9</sup> which had the same spread of association between Enjoyment and Flow.

To complete this analysis set we ran a further Spearman's test between Enjoyment and Knowledge improvement. This gave us an indication of whether positive perceptions of enjoyment were related to

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<sup>9</sup> See chapter 5 Table 5.7



the perception of knowledge learnt. We found a significant positive correlation in both groups, with the PME condition having the stronger shared variance over the ORA group; most likely due to the higher levels of perceived Knowledge Improvement shown for PME.

Finally, in terms of the perception on possum control and management, we found little evidence that higher levels of perceptions on possum control were associated with high knowledge scores. Nor did we find evidence that high Flow perceptions and high possum perceptions were related. This included associations for Enjoyment and Knowledge Improvement. The most logical explanation for these results were that our population sample already had relatively high levels of sympathy and appreciation of the topic before engaging with the study activities, and that this was relatively unaffected by taking part. This was evidenced in the data analysis of the overall level of understanding and concern about possum control discussed in section 7.3.1, and in displayed in Figure 7.3

### 7.9.1 Addressing the Hypotheses

The aim in conducting this study was to investigate the effectiveness of the computer game 'Ora – Save the Forest!' (ORA), when compared to a visually rich computer simulation model of the Possum Management Environment (PME). The learning goal for each activity was to teach pest management and forest health skills, and through the assessment of that goal provide deeper insight into the effectiveness of the SPP design approach. There were two research objectives; (1) investigating knowledge acquisition objectives, and (2) assessing the motivational and enjoyment impacts of the two similar conditions. To meet these two objectives we presented two hypotheses.

The findings of this study support *H7.1: That a computer game experience of pest management and forest health, designed using the Structural Playability Process (SPP), provides a learning environment that supports positive knowledge acquisition.* Our support is based on the statistically significant level of knowledge retention between the pre and follow-up testing points achieved by ORA but not PME. To clarify, knowledge acquisition in this context is the level of knowledge acquired measured against pre-test levels and this includes the post-test and follow-up retention scores, as they are both based upon the distance from pre-test levels.

We also find that the results of the study support *H7.2: That a computer game experience of pest management and forest health, designed using the Structural Playability Process (SPP), provides a learning environment that promotes conditions for a state of optimal experience, or 'Flow'.* The Flow

results are more ambiguous. However, the descriptive trends do show higher levels of positive perception on Flow conditions for ORA than PME. Specifically there was a statistically significant difference between the ORA and PME experience on Feedback and Immersion – time awareness. With 70% plus of ORA participants reporting positive responses in these categories.

### ***7.10 Study Limitations***

The population sample for the experiment was drawn from a University setting. This introduced a bias towards well-educated critical thinkers of an age range where game technology usage would be familiar and commonplace. To gain further insight into the effectiveness of either the game, or the simulation in delivering the learning outcomes, we would need to expand the population sample to be more representative of those whose daily lives are directly impacted by possums and controls. For example; those who live and work in rural areas, come from a variety of educational backgrounds, and sampling from an age range where immersion in technology and gaming is not ubiquitous.

Another limitation of the study was in the time frame that we allocated to the activity, which was only fifteen minutes. This is an incredibly small amount of time in which to address new concepts, both in terms of the subject matter, and in terms of learning a new User Interface. It is also possible that this compressed time frame had a negative impact on the subject's ability to reach a state of Flow. With more time and freedom to explore the UI and experiment with the taught skills we might have seen stronger links between knowledge acquisition and Flow.

### ***7.11 Conclusions***

Through careful design the study contained two computer activities that were differentiated only by the presence of the SPP gameplay system. The study design also reduced possible confounding variables as each condition took place in an identical environment sharing the same equipment. With the core differences between the two conditions being ORA used the SPP designed gameplay to guide the activity whereas PME used a tutor. The learning goals were the same.

The user-study cannot directly measure the SPP itself, but rather draws inferences from the empirically data collected. However, we do conclude that the evidence supports the impact of the SPP designed gameplay to enable positive levels of knowledge acquisition. Both immediately after play and for longer-term retention when measured against the tutor-led baseline activity.

We also conclude that the evidence supports the impact of the SPP designed gameplay to enable positive perceptions of Flow conditions. We propose that if the applied theories of motivation; (Csikszentmihalyi, 1990; Deci & Ryan, 1985; Abraham H. Maslow, 1999), and Skilled Performance (Fitts & Posner, 1967) underpinning the SPP approach were proving effective this would be reflected in positive results collected through the adapted EGameFlow. Indeed we saw good levels of positive perceptions across flow conditions and which were higher overall when compared with our baseline data from the PME.

The baseline comparison data allowed us to see which elements of Flow were most and least well supported by the gameplay. ORA proved statistically significantly different from PME on feedback and immersion – loss of time awareness. We propose that these differences are indicative of the impact of the SPP approach and provide insight on the connections between Skilled Performance and Flow. Refer to section 3.1, Table 3.2 for the matrix displaying the proposed intersection of Skilled Performance conditions and Flow.

# 8

## Evaluation

The literature review (*chp. 2*) revealed a consensus from earlier research that computer games have the potential to operate as effective learning environments. Games stimulate motivation, skill development and affect learning (Aguilera & Méndiz, 2003; Dondlinger, 2007), with the most frequently occurring outcomes and impacts being knowledge acquisition/content understanding and affective and motivational outcomes (Connolly, et al. 2012). Although, O'Neil, et al. (2005) agreed that 'the evidence of potential is striking, but the empirical evidence for effectiveness of games as learning environments is scant'. It is further suggested by Wei & Li, (2010) that 'design of educational games is the key to the balance between education and games'.

This research highlighted several game design models that attempt to bring structure to the design of learning games. Many of these models apply motivation theories to guide the design process. Of these theories, Csikszentmihalyi's, (1990) theory of Flow is prominent. Flow utilising design models are numerous, including the Experiential Gaming Model (Kiili, 2005), Input-Process-Outcome Game Model (IPOGM) (Garris et al., 2002) and the Game Object Model (GOMII) (Amory, 2006). Additional noteworthy models applying Flow in educational game development are the Person-Artifact-Task Model (PAT) (Finneran, C. Zhang, 2003) and the User-System-Experience model (USE) (Cowley et al., 2006). Although these models provide valuable insight in aligning educational theories to game design they reveal a tendency to concentrate on the theory behind educational game design while falling short on being able to directly address the complexities inherent in practical implementation.

### ***8.1 Restatement of the Research Approach***

This PhD research contributes to this body of work by offering the Structural Playability Process (SPP) of educational game design, see *section 3.2*. The SPP was developed to be a practical approach that is capable of taking a game design from initial concept through to playable game. The SPP approach builds upon a deeper theoretical model of game design the SPD, also previously developed by the author (Bradshaw, 2007) *section 2.3*. This thesis presents the design approach of two computer games; "*GeoThermal World*" and "*Ora - Save the Forest!*" Both games being designed and developed through

the practical application of the Structural Playability Process (SPP) of educational game design. See Fig 8.1 for a reminder of the SPP method of mapping educational gameplay.

The SPP approach draws on several theories in psychology. These theories are skilled performance put forward by Fitts & Posner (1967) in their work on Human Performance, the motivational theories of Maslow, (1943) who suggested that growth and self-actualisation of the personality, being a lifelong process, can be driven by learning, and Deci & Ryan, (1985) who see motivation in the form of self-determination and the work of Csikszentmihalyi, (1990) on optimal experience termed as 'Flow'.

The different design and development spaces of the SPP are; Educational, Translation, Design and Engine. The advantage of this new approach is in how it enables the designer to breakdown the gameplay process into a simple set of spaces that can be grasped by all the project stakeholders from client to designer to engine programmer.

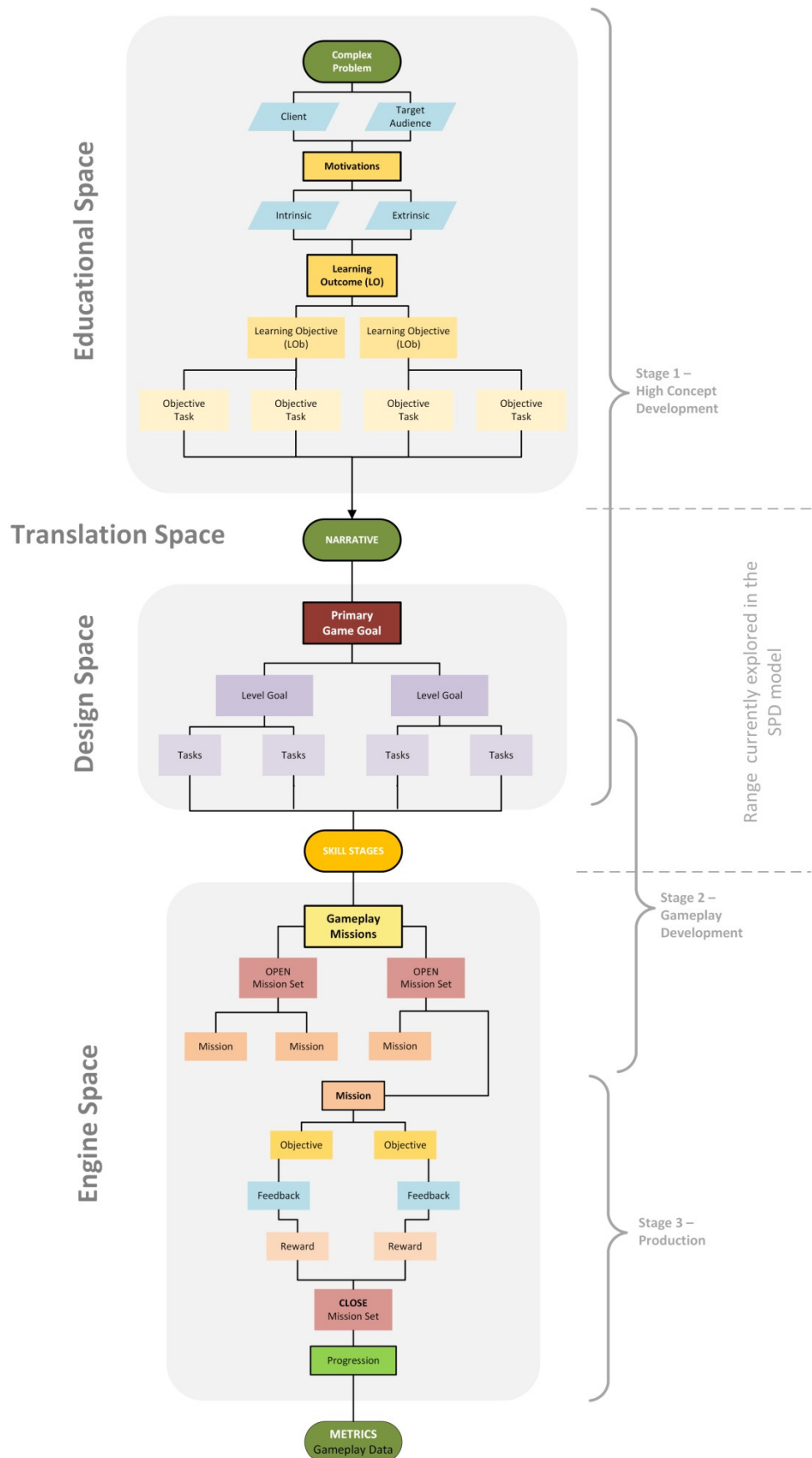


Figure 8.1 - Structural Playability Process (SPP) – Mapping educational gameplay

### 8.1.1 Research Question and Hypothesis

The outcomes of this thesis are framed in answer to the research question: “*What is an **effective design process** for computer games that deliver **structured learning activities**?*” This research question was refined through the analysis of the learning game literature, related learning theories and investigation into the various models, frameworks and approaches. The research strategy is describe below and illustrated in Figure 8.2.

**1) Research Question:** The method for answering the research question was through the application of the Structural Playability Process (SPP). In section 1.1, the research question was broken down into its key properties. The first of these defined the criteria of the research to be a measure of effectiveness. To be **Effective**; where the students learn what is intended for them to learn through interaction with the game. The investigation was loosely structured into two streams, **Stream a)** factors that focused on design and **Stream b)** factors that focused on structured learning.

In Fig 8.2 factors under a) are seen on the left and those under b) to the right, and as with any design process the two streams have overlapping shared components.

#### The Streams:

**a) Design process:** the process that games designers apply when developing computer games.

The process applied in this research was the SPP. It had to meet the requirements for design of the game concept, implementation of the game mechanics and the methods of aligning learning outcomes with gameplay objectives for practical implementation.

**b) Structure learning activities:** characterised by having defined learning outcome/s forming the basis upon which the gameplay is built. These would give rise to skill based tasks that generated goal driven progression which would preferably lead to knowledge transferable outside of the game world (see section 1.1 for definition of transferable).

**2) Development Questions;** Defining the research question led to three game development questions for guiding the SPP application. Two game projects were developed to test the SPP approach as detailed in chapters 4 to 7. Question 1 was answerable under stream a) governing design. Question 2 bridged the two streams and question 3 was concerned with stream b) structured learning.

With the development of these two games it was hoped to discover if the;

1. SPP can be followed as a design approach when presented with a real-world client problem?
2. designer can implement the learning outcome and objectives of the client into a gameplay system that can be built in a game engine?

3. games can meet the learning outcomes of the client through providing the Target Audience with an engaging gameplay experience that provides subject knowledge?

**3) Measurements;** A between subjects design user study was conducted to evaluate the outcomes of each game (*chap. 5 and 7*). The measurement methods were also streamed.

**a) Gameflow:** To infer the value of the SPP design process by focusing on ‘the experience of the design’; how the SPP supported conditions of engagement and enjoyment. This was measured through participant perceptions of Flow conditions through the adapted EGameFlow questionnaire.

**b) Structured Learning:** Whether the gameplay goals, learning objective and outcomes had been met. To assess the value of the SPP on learning outcomes through knowledge acquisition levels.

**4) Answer Research Question:** To enable answering of the research question a hypothesis was formed:

*H<sub>1</sub>: The Structural Playability Process of educational game design acts as an effective design approach for delivering structured learning activities.*



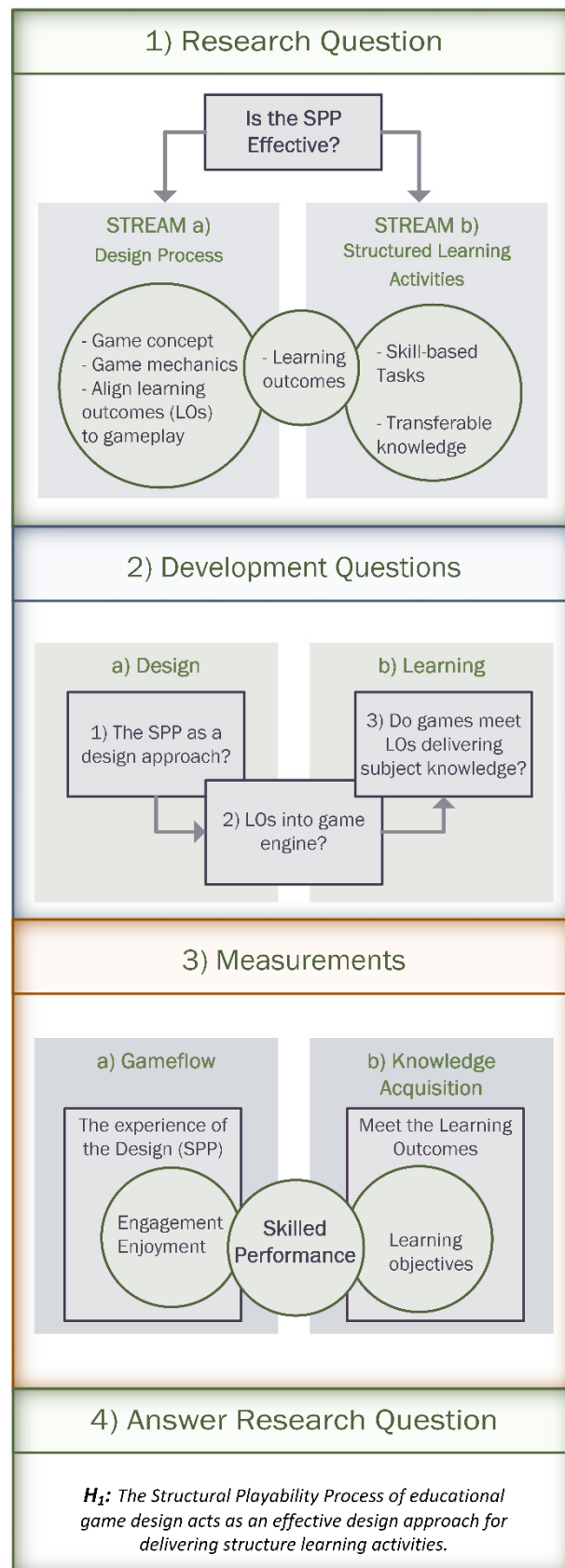


Figure 8.2 Research strategy overview

## 8.2 The Game Projects

In support of the hypothesis two very different games projects were undertaken; '*GeoThermal World*' (Geo) and '*Ora – Save the Forest*' (Ora). Each game had a unique concept developed from the basic requirement for a playable game that explored a specific educational problem. Development of the games allowed testing of the hypotheses under the two streams which evolved from the research question and strategy (see Fig 8.2).

Academics have developed and are developing design models that attempt to bring some clarity to the complexity of game development. The intention of the SPP is to provide a practical structure for the design and development process of educational games. It intends to provide a consistent design framework and developmental scaffold for a game project. Not only does the SPP handle the concept of the design but puts a clear structure in place for the mapping of the gameplay experience. It attempts to simplify the heart of the game project, in terms that can be understood and followed by game project stakeholders and experienced as engaging gameplay by the intended audience.

### 8.2.1 Validity of the SPP

The purpose in developing the SPP designed games was as a means to provide insight into the robustness and consistency of the SPP approach. The intention was for similarities between the two projects to result from factors introduced by the application of the SPP and not the gameplay world or subject topics. For the SPP to be judged as successful it should support consistent outcomes across the two streams for both games. To add strength to the validity of the SPP as a generalizable approach and to reduce confounding variables the two game projects were very different from each other. Table 8.1 illustrates the differences between the two games.

Table 8.1 An illustration of the difference between the game projects:

Attributes	GeoThermal World	Ora – Save the Forest!
<b>Client</b>	Dept of Geological Sciences, Mighty River Power	Landcare Research
<b>Co-researchers</b>	Geology specialist and Educationalist	Ecology research scientist
<b>Game World</b>	Realistic, Immersive Geothermal Landscape.	Cartoon style 3D/2D simulated forest
<b>User Interface</b>	Simple UI	Complex UI
<b>Genre</b>	1 <sup>st</sup> person, world centred: free roaming exploration	3 <sup>rd</sup> person, UI centred: strategy/analysis based play
<b>Learning Outcome</b>	To apply a systematic and conscientious approach to geothermal exploration.	To gain a realistic appreciation that management of an ecosystem is a complex problem.
<b>Objective Tasks</b>	Take measurements and record data Characterizing the geothermal features.	Monitor Environment Manage Environment
<b>Narrative</b>	A young Geologist directly out of university lands an exciting new job mapping a 'Green' (i.e. grassroots, no previous drilling) geothermal prospect	The public is the hero saving the fragile, beautiful but resilient eco system from the jaws of the invasive Bushtail Possum.
<b>Gameplay Goals</b>	Explore the environment and Characterizing Hot springs	1. To repel an army of mammalian pests led by marauding possums. 2. save the native flora and fauna 3.restore the forest ecosystem to its former glory
<b>Gameplay Features</b>	Geothermal pools, geothermal tools, geologists geothermal notebook	Research centre, operational management tools, native trees, Possums, nurture system, forest health graphs.

The tangible similarities that the SPP introduced to the final game projects were:

- The application of Skill Stages; for pacing the learning content which fed into the Mission System.
- The Mission System; the means by which the player interacts with the learning content.
- The use of a non-player character for in-game mission delivery.
- A mission log detailing the mission instructions and objectives.
- developed in the Unity 3D game engine and delivered on PC using a standard keyboard and mouse.

Assessing the outcomes from both games provides a clearer idea of which factors in the design were consistent and which required greater focus.

### 8.3 Design Challenges

A design process is almost always a circular, iterative process. Following the SPP approach, with its underlying framework of skilled performance theory, provides a scaffold upon which an enjoyable, engaging player experience can be designed. In the user studies, Flow conditions in combination with game heuristics were used as a measure of player enjoyment (Fu et al., 2009; Sweetser & Wyeth, 2005) upon which inference as to the value of the SPP could be drawn.

The 'Spaces' of the SPP approach brought consistency to the complex, circular, game design process by applying structure to the game concept. In summary, the 'Spaces' of the SPP start with 'Educational' where the games' learning outcomes are defined. This is followed by the 'Translation' space where the learning outcomes are embedded into a suitable narrative. In the 'Design' space the gameplay goals are developed within the narrative context before their detailed implementation into the mission system of the 'Engine' space (*refer back to chap. 3 for full details*). This framework sets conditions for player experience, by providing suitable challenges that keep pace with player skill levels (Csikszentmihalyi, 1990; Deci & Ryan, 1985; Fitts & Posner, 1967).

From the designers perspective, the 'complex problem' of each game brought unique design challenges. In *GeoThermal World* this involved the complete creation of a realistic geothermal landscape that was able to hold up to the expert scrutiny of trained geologists. For the *Ora* game it was the incorporation into the gameplay of the mathematical simulation model; a model that brought a rigid set of functional parameters. These imposed conditions set the tone of the design process as they formed the infrastructure upon which the gameplay was built. The *Geo* world construction provided a more flexible design approach, as the world acted as a sandbox to which 'Missions' could be applied. Whereas for *Ora*, the pre-programmed nature of the simulation model imposed a structure which the gameplay missions had to be designed around or incorporated into.

As the *Geo* game brought no pre-defined methods for interfacing with the gameplay world, all the gameplay tools were custom built. Although this was a challenge for designer, programmer and client, there was also a great deal of flexibility in their development. This design flexibility had the outcome of providing gameplay tool functions that were closely synced to the gameplay pacing. The geologists' digital notebook proved to be most noteworthy in its functioning and integration with the other gameplay features. However, in *Ora* the predefined nature of the simulation code and function of the pest management operation defined the tone of the gameplay. This made the pacing of player challenge in the skill stages more restrictive. Before incorporation into gameplay the simulation model was already a sophisticated tool for use by scientists. The designer and coder had to cope with the complex nature of

how the model handled pest management strategies from its predefined viewpoint. Therefore, the challenge for the gameplay design was to not only introduce the game's concept to the player but also to be well formed enough to interpret the function of the model and its scientific outputs.

These types of design challenges would have to be faced by any designer working in the field of educational games. In this research context, the author had the combined roles of research investigator and designer as an advantage (see chap. 3, Fig 3.8). In the role of designer the author was already deeply familiar with the SDP model of design (Bradshaw, 2007, 2010). The SPD supported the 'designer' role through the theoretical application of the Skilled Performance game design method (see section 2.4.2). It was the theoretical structure of the SPD model that expanded into the 'Spaces' framework of the more practically oriented SPP approach. In simplified terms; on first encountering the game topics the designer was structuring the 'complex problem' in terms of the Four Principles of a Skilled Performance. Described in short;

- (1) the game concepts should follow a logical structure of goal driven activities. Where the goal is clearly related to the gameplay tasks and feedback is provided on the player progression.
- (2) the complexities of the game concepts were thought-mapped in terms of the Three Phases of Skill Learning (Bradshaw, 2007; Fitts & Posner, 1967). In gameplay design terms the skill phases are comparable to levels of gameplay difficulty. They structure the gameplay into Early (Cognitive), Intermediate (Associative) and Final (Autonomous) levels of play.

Both Geo and Ora's gameplay levels sat within the Early (Cognitive) phase, acting as tutorial entry levels. With their purpose to implant the basic concept, framework and subject knowledge required for the more complex gameplay that would follow in later levels.

### 8.3.1 Forming the SPP 'Spaces'

At the start of the '*GeoThermal World*' (Geo) game project the skilled performance (Bradshaw, 2007; Fitts & Posner, 1967) approach of the SPD model was first applied to the complex problem. However, the educational gameplay of Geo called for a method to define and map the academic problem, before development into the gameplay narrative. At this point the Skilled Performance principles of the SPD were combined with the new theories of motivation; self-determination (Deci & Ryan, 1985; Maslow, 1999), Flow (Csikszentmihalyi, 1990) and the teaching and learning practice, of forming learning outcomes (Allan, 1996; J. Biggs, 2003).

Applying these combined methods led to formation of the SPP, particularly the Educational Space. The Educational space sorts the information of the game concept readying it for translation into a gameplay

narrative. Its key function is scoping the problem. It is the first step in the game design process. In terms of the SPD model it happens before the stage 1; progression revision (see section 2.3.2).

For the SPP to possess validity as an educational approach to design, it required clearly defined steps for mapping learning outcomes and objectives. Outcomes that could be met by the learner and measured by the teacher (Allan, 1996). Stage 1 of the SPD; *high concept development*, defined how a game concept would be developed for generation of a skilled performance. The application of learning outcomes to support motivation was a logical step for the building of a 'skilled performance', and a skilled performance is what we wish our player-learner to achieve. When describing the Flow condition of 'merging action and awareness' Csikszentmihalyi, (1990) p54, clearly states that Flow '*does not happen without the application of Skilled Performance*'. In the educational space, creating the foundations of a skilled performance from the learning outcomes and objectives provides the structure and goal orientation described by the first two skilled performance principles; Structural and Goal. In summary, those principles state that a skilled performance always involves an organised sequence of activities that are goal orientated and directed. Therefore, the pathway to achieving the learning outcomes would come through the application of skilled performance conditions.

When the Ora game was commissioned the structure of the Educational Space was firmly in place. Ora provided the opportunity to cleanly apply the structure of the educational space to a new complex problem. As a result the communication between client and design team was well structured from the outset making the resulting client side design and game-plan documentation straightforward to create. The practical outputs from the Educational stage for both games were sets of documentation providing a road map that the designer used to detail the game concept to the client and to the production team. In Geo this documentation was more fragmented and light in comparison to the depth of scope that was outlined for Ora.

With the advent of the Educational space the SPD Structure was clarified into the remaining spaces. The structures of the Translation and Design Spaces simplified and embedded the theoretical complexity of stage 1 and 2 of the SPD model; High Concept Development and Gameplay Development. The Translation Space guided by the SPD model not only deals with the newly formed narrative, but it begins to sort the narrative components into elements that can be developed into gameplay mechanics. In both Geo and Ora it was the mapping of the narrative elements into gameplay mechanics which led to the cross over into the Design Space.

The Design Space is concerned with level planning and mapping. In each case; Geo and Ora, the gameplay levels goals and tasks were paced by mapping to the SPD's 'Phases of Skill Learning' e.g. Cognitive, Associative and Autonomous. The Design Stage manages the gameplay planning. It is underpinned by the theoretical Skill Stage mapping of the SPD model. The Skill Stages that comprise each game hold the gameplay detail for increasing challenge and task difficulty, which embeds the learning. Both Geo and Ora's gameplay were built through the application of Skill Stages. As a method of achieving a skilled performance, Skill Stage mapping provides a scaffold upon which the psychological requirements of the three Phases of Skill Learning can be met.

The Engine Space was borne out of the Skill Stage mapping; as the logic sequence of a Skill Stage fits into a format that can be applied inside a game engine. It is a simple, practical approach for linking the learning outcome, gameplay goals and narrative together as playable missions.

As the Geo game concept developed it was found that Stage 2 of the SPD – Gameplay Development could be pulled-out and restructured as the new Engine Space. When the team began to write the gameplay missions for Geo, it was found that the Skill Stage mapping approach of the SPD provided a practical structure that could be directly interpreted by the designer and coder into the game engine. The skill stage structure provided a logical scaffolding process, not just for writing mission content on the design side, but also realised as the mission structure within the engine. The SPP approach takes the theoretical SPD Skill Stages and re-maps them as the mission system seen in the Engine Space. Therefore, Skill Stages become less of an academic exercise and more of a practical method for implementing gameplay missions.

In this way the Mission System found in both games, was developed into the Unity game engine and could be expanded and adapted as new missions were written. In Geo, the mission structure was designed after the gameplay missions were written, building upon what was learnt in Geo. The Ora mission structure was created in the engine first, and the missions were then written to follow that structure. Initially this proved to be a more streamlined approach. However, as is the case in many projects, time and budgets pressures impacted on the consistency in the delivery of this approach. Figure 8.4 offers a direct comparison of the two Mission structures as seen in the game engine editor.

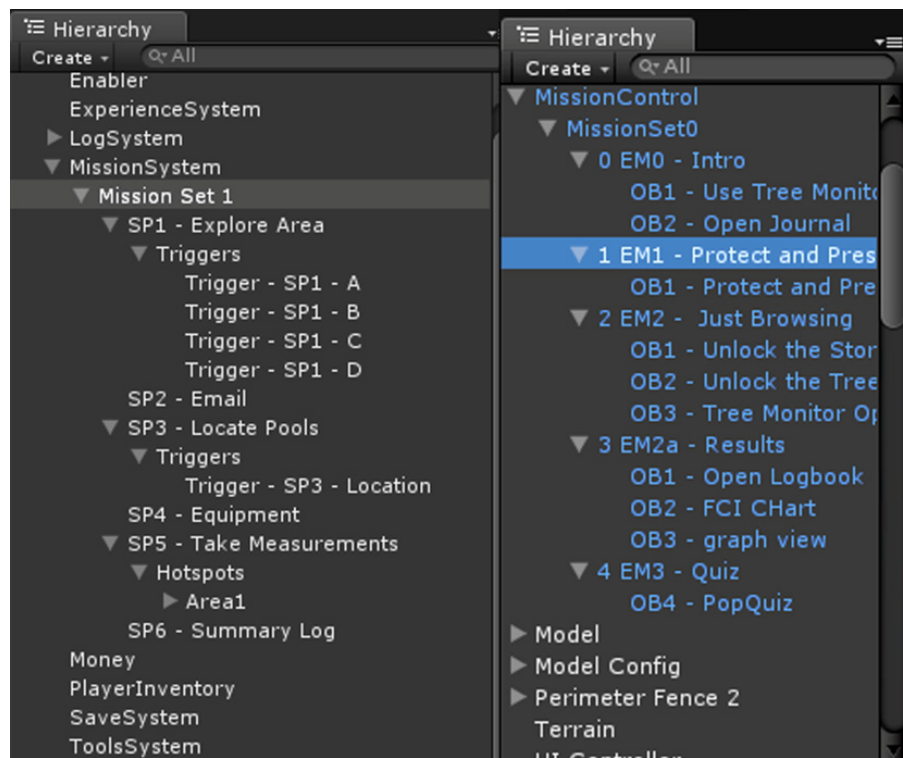


Figure 8.3 - Comparison of the in-engine mission system structure between Geo (left) and Ora (right)

In Fig 8.4 the in-engine mission structure of Geo (left) was newly developed, it was being adapted as the game concept was being explored. In both systems the mission objectives were created as standalone entities within the mission body. The mission system of Ora (right) benefitted from the first iteration of Geo, which clarified the structure of the mission objectives in the mission set hierarchy (seen in the left of each image). The Geo and Ora mission systems were coded into the engine by two different programmers. The programmers followed the mission logic provided by the designer, and the designer created the mission as structured by the Engine Space.

The implementation by two different programmers lends support to the practical benefits of the Engine Space and lends support to the value of the SPP as a practical approach. If the mission system structure does provide a logical, practical method for guiding the programming of missions into an engine, then it should be seen to deliver a consistent experience in the resulting gameplay experience, as this engine-based system is the delivery method for the structured learning activities. It is this framework that controls the interaction with the game-world, and the method for delivering the pacing, timing and progression for developing player skills.



### 8.4 The Stream a) – Evaluating the Design process

In the user studies undertaken (chap 5 & 7), the design process was assessed for Csikszentmihalyi's conditions of Flow through player survey, using an adaptation of the EGameFlow questionnaire (Fu et al., 2009). Although the EGameFlow categories do not map directly with the Flow categories as Csikszentmihalyi's presents them, they do provide a '*concise model of enjoyment in games that are structured by Flow*' (Sweetser & Wyeth, 2005).

For clarity, Table 8.2 restates the EGameFlow categories next to their related Flow condition and Skilled Performance principle. It is important to reiterate these relationships so a judgement can be applied as to the effectiveness of the SPP. We have theorised (section 3.1.2) that Skill Performance principles are closely linked to the conditions of a Flow experience. However, the EGameFlow scores cannot directly measure the SPP but rather act as the indicator upon which inferences of the effectiveness of SPP designed games can be made. This is investigated in the following section through a comparison of positive response trends of both studies.

Table 8.2 A reference between Flow, EGameFlow and Skilled Performance

EGameFlow Category		Flow Condition	Skilled Performance Gameplay Principle
Challenge		1. A Challenging Activity That Requires Skills	1. Structural, 2. Goal, 3. Clarity, 4. Comparison
		2. The Merging of Action and Awareness	1. Structural
Goal Clarity	Feedback	3. Clear Goals and Feedback	2. Goal, 3. Clarity , 4. Comparison
Concentration		4. Concentration on the Task at Hand	1. Structural, 2. Goal 3. Clarity, 4. Comparison
Autonomy		5. The Paradox of Control	3. Clarity
Immersion		6. The Loss of Self-Consciousness	1. Structural, 2. Goal, 3. Clarity
		7. The Transformation of Time	

In our studies the EGameFlow (Fu et al., 2009) categories provide a measure of the attributes of Flow which when experienced together can be taken as a level of enjoyment of the experience.

#### 8.4.1 Comparison of Positive Response Trends

Fig. 8.5 displays a comparison of the positive responses on Flow conditions between the Geo and Ora games. As can be seen, although the scores are different between the two games, with Ora having the lower overall Flow experience, the results pattern is remarkably similar across the categories. There is a general upwards trend between Challenge and Concentration, with Feedback scores the same.

Geo saw the first iteration of the SPP. The differences in Feedback scores could be a result of refinements in the design of feedback in the rewards and progression of the gameplay missions. The weakest points in both game's designs are seen in perceptions of Autonomy. Autonomy is the category that relates to Flow's 'Paradox of Control'. Although autonomy was felt more positively in the Geo gameplay at over 60%, it only felt positive to less than half of the players of Ora.

The final adapted EGameFlow condition combines the last two conditions of Flow; Loss of Self-consciousness and The Transformation of Time. It appears that the gameplay had a positive impact on both of these Flow conditions, with Geo perceived as more immersive. One reason for the difference between the Immersion scores, could relate to the amount of time participants played each game. For Geo the participants played for approximately 1 hour and 30 minutes, compared to 15/20 minutes for Ora. The short duration of the gameplay for Ora could also account for the lower autonomy scores, as Ora players could perhaps have felt less in control, as they had less time to become involved in the world. The final category of Enjoyment trends highly for both of the games.

In summary, it appears that the SPP designed gameplay proved to be an enjoyable way to interact with the different subject topics of each game.

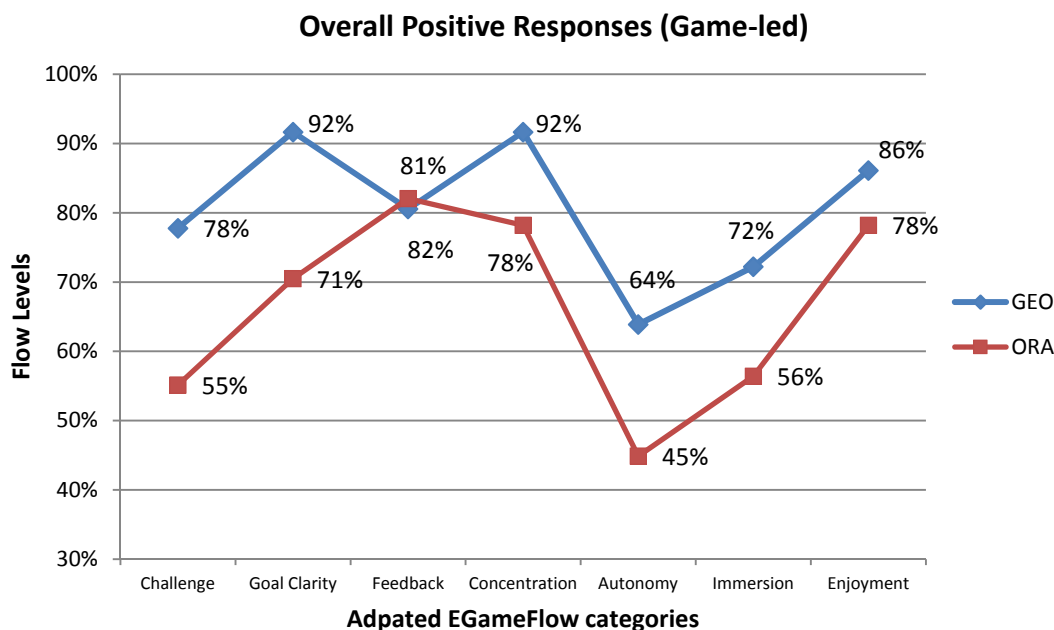


Figure 8.4 – A comparison of the positive responses on Flow perceptions for Geo and Ora

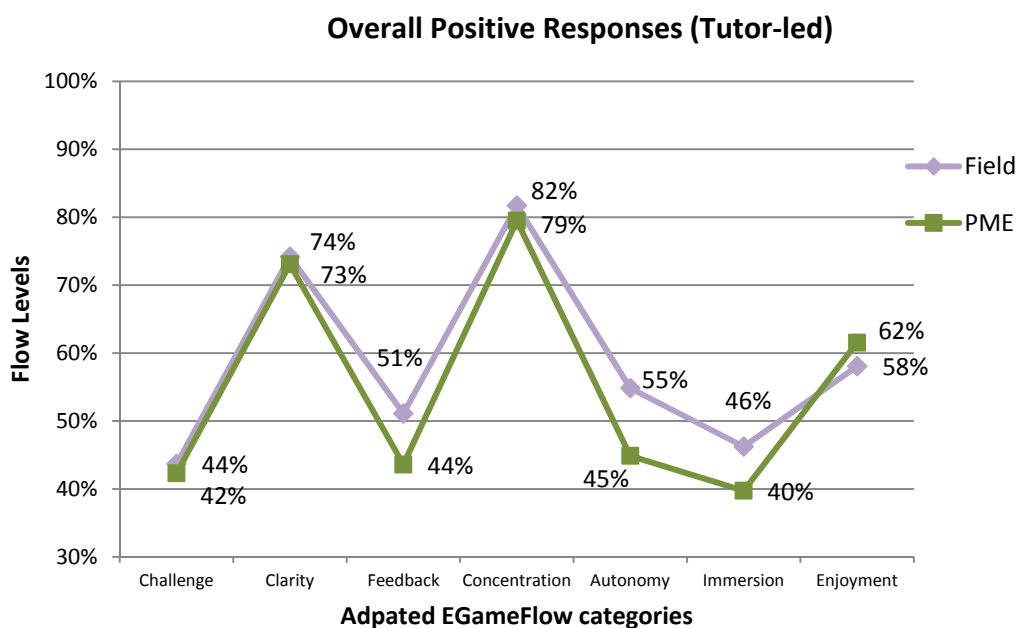


Figure 8.5 – A comparison of the positive responses on Flow perceptions for the non-game conditions

To gain a clearer picture of the trends seen in Fig. 8.5, and to provide further insight into the impact of the SPP as a methodology, the same comparison of positive perception of Flow conditions were mapped for the tutor-led activities of the two user studies, Fig 8.6. The exploratory baseline activity for Geo was a field-trip (Field) and for Ora this was a scientific simulation of a possum management environment (PME), which shared the UI and 3D world environment of Ora. The two alternate tutor-led activities followed the same set of tasks that were undertaken in the gameplay of Geo and Ora. Overall, what is seen is a lower set of positive perception in both cases for Field and PME. Higher peaks in positive

perceptions are found in the categories of Goal Clarity and Concentration. These two categories also display positively in the game conditions. In contrast, all four conditions show a trend of relatively low positive perceptions for Autonomy. In Immersion, the two game conditions diverge from the two tutor-led conditions, with the games showing an upward trend in contrast to the downward trend of the tutor-led experience. The baseline category of Enjoyment is also considerably lower in the tutor-led activities.

When looking at the graphs in Figs. 8.5 and 8.6, it appears that Fig. 8.5 displays higher levels of the qualities associated with Flow and enjoyment. These trend patterns can provide an indicator of where the SPP application offers consistency. To be indicative of a Flow State it would be expected that high positive perception levels would be seen across all of the categories. If the positive scores are an indicator of 'goodness', then application of SPP design requires improvement in the categories of Challenge, and Immersion, with the most need for improvement clearly seen in Autonomy.

#### **8.4.1.1 Statistical Test on Comparison Trends**

In support of consistency for the SPP approach a Mann-Whitney U (MWU) test was run to look for differences between the scores of on Flow perceptions between the games Geo and Ora. Unlike the previous trends data which just looked at the positive perception levels, (Figs. 8.5 and 8.6), the MWU took account of both negative and positive responses to the Flow categories.

Finding significant differences in the results between the different game designs could indicate possible points of weakness that the SPP approach was unable address. The positive trends data provides an indication of which categories require boosting. Whereas, the MWU test results provide deeper clues as to where within each game, the design was being most affected.

Out of the seven categories, which included Enjoyment, only one statistically significant difference was found. That difference was in the category of Concentration ( $U = 84$ ,  $p < .018$ ) with Geo having the higher mean rank. A second category nearing significance was Challenge ( $U = 98$ ,  $p > .058$ ) again with Geo having the higher mean rank. The remaining categories of Goal Clarity, Feedback, Autonomy, Immersion and Enjoyment showed no difference between the two game experiences, although the mean rank was higher across the board for Geo.

As seen in the positive perception trend comparisons (Figs. 8.5 and 8.6) Geo provided the gameplay experience that most closely reflected a Flow state. If we use Geo as our baseline for positive results this data tells us that Ora was weakest in providing the balance between the challenge to be undertaken and

the skill level of the players, and it also tells us that ‘concentration on the task at hand’ was not well supported in the Ora gameplay. Reasons for the outcomes are most likely due to the different playing styles of the games. For example, Geo promoted self-directed exploration of the 3D environment with its simple ‘sandbox’ playing style, whereas Ora had a UI heavy experience with the players cognitive resources split between understanding the task and working with the UI. The cognitive load of the science model outputs could also have an impact. In hindsight the complexity of the Ora gameplay was high in comparison to the open free-roaming, naturalistic aspect of Geo. The timescale will also have had an impact on comprehension, with 90 minutes playing time for Geo compared to 15-20 minutes for Ora.

#### **8.4.1.2 Comparison of Shared Variance Trends**

Another set of analyses performed from the user studies data were correlations. Of particular interest to the design process were the correlations between the Flow conditions and the baseline Enjoyment, as enjoyment of the gameplay experience indicates a positive degree of engagement with the subject. Positive perceptions of enjoyment for both games were over 70%, compared with the tutor-led activities which were both below 65%.

The Enjoyment and Flow association data was comparable across both user-studies making it possible to compare the levels of shared variance between the two SPP designed games. Shared variance is calculated to show the percentage of association between two data points. For example, where perceived enjoyment helps to explain nearly 31 percent of the variance in respondents scores on perceived challenge. The reason for comparing the levels of shared variance is to highlight any patterns that could indicate the impact that application of SPP brings to the two game designs; in this case by comparing the association between the baseline Enjoyment levels with participant perception of Flow conditions.

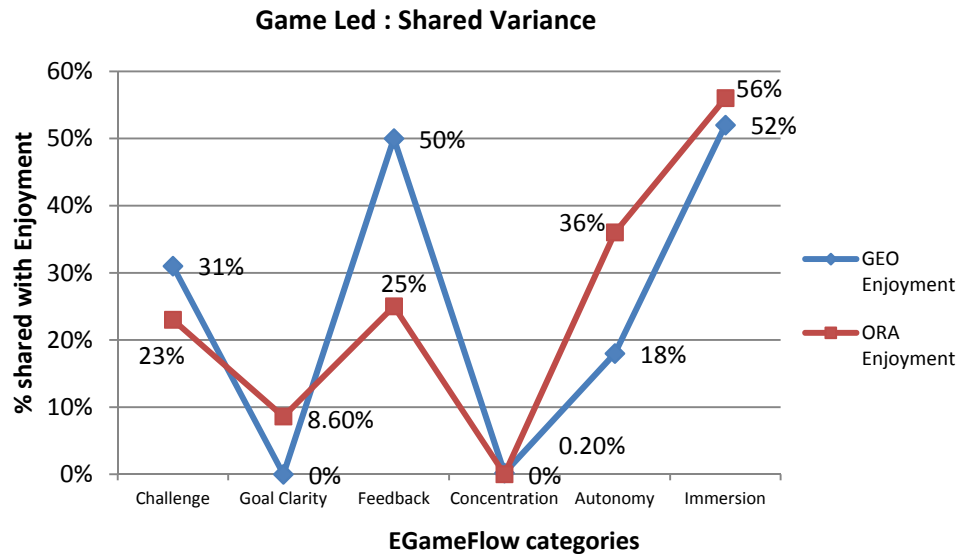


Figure 8.6 – A comparison of the correlation patterns of Flow and Enjoyment between Geo and Ora

What we are seeing across Fig. 8.7 is a similar pattern of shared variance across the six Flow categories. There is a range of medium to strong degrees of association in four out of the six Flow categories for both games, with corresponding weak associations for both game in Goal Clarity and Concentration. The strongest association seen in both games is for Immersion where the shared variance for both games was over 50%.

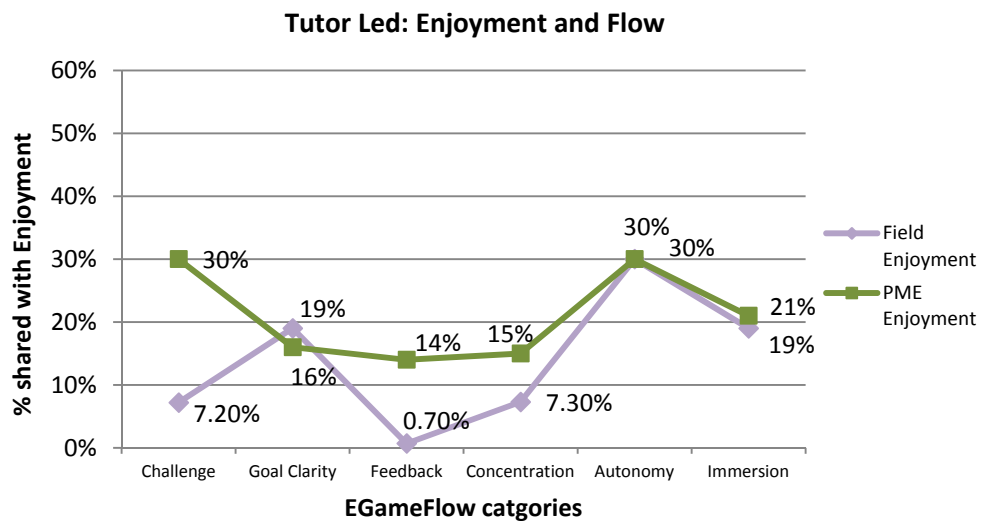


Figure 8.7 – A comparison of the correlation patterns of Flow and Enjoyment between Field and PME

When this is compared the patterns of shared variance (Fig. 8.8) for the tutor-led activities the levels of association between Flow and Enjoyment are lower. The patterns are also different in nature from the game-led distributions. It appears that the peaks and troughs of the game-led associations are relatively consistent unlike the associations for the tutor-led activities. It can be inferred from this data that the SPP is having some unifying impact that is affecting the association between enjoyment levels and positive perceptions on Flow.

### 8.4.2 Answering Development Questions 1 and 2

1. *Can the SPP be followed as a design approach when presented with a real-world client problem?*

Even with the different design challenges that the individual complex problems brought, the SPP proved to be a reliable scaffolding system. The Educational Space with its use of learning outcomes, objectives and tasks to breakdown the client side problem aided discussion of the 'problem' and enabled development of initial concept documentation. The Educational Space provided a basis for communication between designer and client that kept the early stages of the design on track. The theoretical knowledge of the Skilled Performance Principles and Phases of Skill Learning acted as a sound underpinning when moving the design concepts forward from Educational Space into the gameplay focused Translation and Design Spaces.

Even though the two game concepts and their resulting games were very different in scope, it can be inferred from the EGameFlow results that the SPP provided a level of consistency to their outcomes. In simple terms this was seen in higher levels of positive perceptions on Flow conditions and baseline enjoyment of both game-led activities over the two tutor-led activities. It is proposed that this consistency was achieved through the game-content being structured via the 'Spaces' and formed into skill stages, which in turn led to the formation of the in-game mission-sets.

Discussion of the Skill Stages method leads to the second of the development questions:

2. *Can the designer implement the learning outcome and objectives of the client into a gameplay system that can be built in a game engine?*

The Mission set structure of the SPP Engine Space proved to be an effective method for interpreting the learning outcome, objectives and tasks outlined in the Educational Space. Fig. 8.9 illustrates the connection between the logical structure of the SPD Skill Stage (top) and the structure of the SPP Engine Space's Mission System (bottom). To elaborate, the Skill Stage 'Challenge' becomes the content of the 'Mission', the 'Tasks' the 'Objectives', 'Feedback' into 'Feedback' and so on until the goal of the challenge has been met and the gameplay is progressed. It is this Skill Stage mapping process presented as the Engine Space's Mission System, which enables the practical implementation of the learning content's gameplay's goals and objectives.

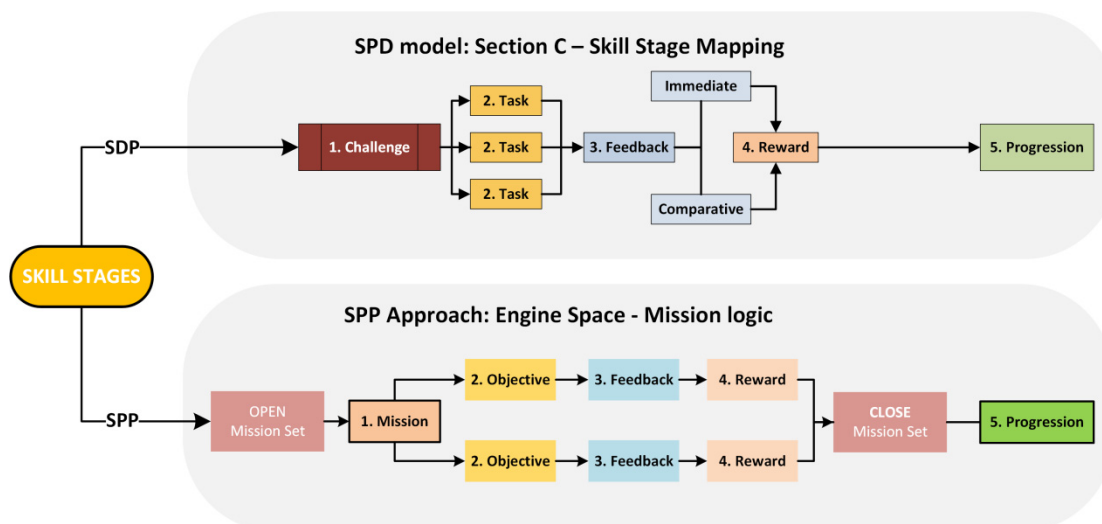


Figure 8.8 – SPD; Skill Stage Mapping and SPP; Mission System Logic

In answer to the second question it is possible to use the SPP to implement the learning outcome and objectives of the client into a gameplay. This is done through structuring the gameplay as Skill Stages, then using that mapped content to form the gameplay missions in-engine, where the designer implements the learning outcome and objectives of the client.

#### 8.4.2.1 Assessing SPP, Skilled Performance and Flow

In chapter 3 we argued that the Skilled Performance principles and Phases of Skill Learning provide a structure that could support the conditions of Flow to arise. The SPP, with its gameplay principles deriving directly from an understanding of Skilled Performance conditions, uses techniques such as Skill Stage mapping and it's practical implementation as a mission system as part of its 'Spaces' structure.

In Chapter 3 (section 3.1.3.1 Table 3.2) a matrix was presented that provided a theoretical map of the intersection between Skilled Performance and Flow conditions. The user studies, through the EGameFlow perception scores, provided evidence which can now be mapped in support of those theorised links. Although the EGameFlow and Flow categories to do not map directly with each other, they do provide a general indication of the strength of the links.

Table 8.3 recreates the matrix from Table 3.2 with the addition of the EGameFlow positive perception scores; positive perception scores representing the percentage of those who either 'agreed' or 'strongly agreed' only. The matrix presents Csikszentmihalyi's Flow categories on the top row, followed by the EGameFlow scores of Geo and Ora, below. The individual scores for each game are then given as an averaged below. Following on from the EGameFlow scores is the matrix of Skilled Performance



conditions in their theoretical mapping. As both games were only of the cognitive Phase of Skill Learning the other two Phases; Associative and Autonomous are not shown.

Table 8.3 - A Results matrix displaying the intersection of Flow, EGameFlow scores and Skilled Performance conditions

Skilled Performance Conditions	Flow Conditions - the conditions for and of an optimal experience															
	For – Can be designed for										Of – experienced by the user					
	1. A Challenging Activity That Requires Skills	2. The Merging of Action and Awareness	3. Clear Goals	4. Feedback	5. Concentration on the Task at Hand	6. The Paradox of Control	7. The Loss of Self-Consciousness	8. The Transformation of Time								
Adapted EGameFlow positive perception scores																
EGameFlow (top)	Challenge				Clear Goals		Feedback		Concentration		Autonomy		Immersion			
Geo (left)	78%	55%			92%	71%	81%	82%	92%	78%	64%	45%	83%	83%	75%	65%
Ora (right)																
Av (bottom)	66.5%				81.5%		81.5%		85%		54.5%		83%		70%	
Skilled Performance principles																
1. Structural	●		●						●				●			
2. Goal	●				●		●		●				●			
3. Clarity	●				●		●		●		●		●			
4. Comparison	●				●		●		●							
Phases of Skill Learning																
1. Early (Cognitive)	●		●				●		●							

● represents the most optimal intersections between Flow and Skilled Performance

%	90	80	70	60	50	40	n/d
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As the SDP and SPP build upon skilled Performance as a scaffold theory, knowing the pattern and strength of this mapping helps to provide a picture of how the underlying theories of the Structural Playability Process are performing in a real gameplay capacity.

#### 8.4.2.2 Analysis

The highest ranges of positive scores seen in table 8.3 are in the eighties and cover Clear Goals, Feedback and Concentration, with the addition of 'The loss of self-consciousness. The Skilled Performance principles mapped strongly to goals, feedback and concentration, as did the conditions of the cognitive phase of learning. Therefore, it is promising that the adapted EGameFlow results reflect this. However, it is a little surprising that 'Challenge' does not show as strongly. Challenge is a reflection of the mapping undertaken in the Educational Space and is the starting point for pacing each Skill Stage. It appears that although Challenge has a score in the sixties, closer attention needs to be paid to how the SPP formats and delivers challenges.

The weakest mapping is seen for the 'Paradox of Control' in Flow and 'Autonomy' in EGameFlow. The positive perceptions of this Flow condition are low in comparison to the others. It is also an area not as well mapped to Skilled Performance. At present the SPP is having an overreliance on the Clarity principle to provide for the feeling of control and autonomy in gameplay. Therefore, closer attention should be paid to supporting this part of the Flow experience in future gameplay designs.

The Flow categories of 'Loss of self-consciousness' and 'Transformation of Time' are combined in the adapted EGameFlow questions. Here they have been split out, as this gives a clearer perception of how participants felt on the two final aspects of Flow. 'Loss of self-consciousness' is judged on how emotionally connected and absorbed the player felt whilst playing the games. It appears that application of the Skilled Performance principles in the design were able to support that emotional sense of immersion. The conditions of the cognitive phase of skill learning were as not mapped to this Flow category, as it is anticipated that the players would be too challenged by the new skills being presented to feel emotionally connected. However, it appears that the game design was able to support this aspect of Flow.

Finally, the 'Transformation of Time' is something that can be measured, but is challenging to specifically design for. This is why there is no direct mapping for this Flow condition with Skilled Performance. The fact that this Flow condition displays such positive scores infers that the SPP and its use of Skilled Performance have combined to support the gameplay experience.

The most obvious drawback seen in this mapping is the lack of EGameFlow scores for 'The Merging of Action and Awareness', so data can't be provided to support this category using this method.

Although the EGameFlow provides a validated and reliable tool for measuring gameflow in educational games, it requires a more specific adaptation if it is to act as an informative measure for guiding and reviewing the SPP. It requires new categories of question that more clearly investigate the relationship between how Skilled Performance and Flow work in support of SPP designed gameflow.

### ***8.5 Stream b) – Evaluating Structured Learning***

In the User Study chapters 5 and 7 the application of the SPP was assessed for its ability to deliver structured learning activities. Levels of Knowledge acquisition were assessed through a skills test. The skills test for each game comprised of a set of multiple choice questions (MCQs), a visual/spatial style question and a short answer, open ended question. In both studies the participants were tested

immediately pre and post activity. In addition the participants of the second study Ora were tested again in a follow-up, four weeks after participation.

Unlike with the 'Flow' scores the 'Knowledge Acquisition' scores were not directly comparable due to the different subject topics and marking criteria, however a similar pattern was found with the results. In both studies there was a statistically significant difference found between pre and post-test knowledge levels. All participants experienced a post-test increase in knowledge levels from pre-test levels. This was the case in both game-led activities and tutor-led activities. These results show that both styles of learning; game-led and tutor-led, produced a significant impact on participants' subject knowledge.

An independent-samples t-test, between the game-led and tutor-led learning gains deltas, found no statistically significant differences. This outcome was found to be true in both user studies, although it can't be said that the outcomes of the game-led or tutor-led activities are the same. It can be argued, in the case of games built following the SPP, that they are not significantly different to a traditional teaching style in achieving results of a similar standard.

However, in the additional follow-up skills test conducted in the Ora user study after four weeks, knowledge retention remained higher for the game-led condition than the tutor-led. Knowledge levels of the tutor-led condition had returned to a state where no significant change could be detected from their pre-activity levels. However, the game-led participants had retained a significant upwards change from their pre-test levels.

These results suggest the possibility that the SPP designed gameplay, in the delivery of its learning outcomes through the structured learning activities, had had a greater impact on participants' ability to retain the knowledge taught during the activity. This lends support to the application of skill stages that take account of Skilled Performance principles, as they house and pace the learning outcomes within a narrative designed to trigger participant motivation.

Under Stream a) Flow conditions, measuring the effects of the gameplay design were found to have higher positive levels, and in some case statistically significantly higher levels, than those measured for the tutor-led experiences. Correlation tests were undertaken to investigate if there was an association between the knowledge acquisition levels and perception on Flow conditions. Unfortunately, across each study and in each condition; tutor-led and Game-led, no significant association between the Flow categories or Enjoyment perceptions could be found.

Although the indications are there for such an association, at this time it was not possible to provide a definitive statistical link between the games designed using the SPP and knowledge acquisitions levels. Even if no association can be proved, there is the outcome that the SPP-designed games promote similar levels of knowledge acquisition to traditional methods of teaching, and importantly they proved to be a more enjoyable method of learning the subject knowledge than the traditional tutor-led approach.

### 8.5.1 Answering Development Question 3

Question:

*3. Do the games when complete meet the learning outcomes of the client through providing the Target Audience with an engaging gameplay experience that provides subject knowledge?*

The games tested in each user study were able to meet the learning outcomes of the client, as they provided an effective method for increasing participants' subject knowledge. This was seen through the significant increase in knowledge scores from pre to post-test levels. Further evidence that the gameplay experience was engaging is seen in the knowledge retention levels in the Ora game-led experience over the tutor-led levels.

Unlike the Geo user study the design of the Ora experiment reduced the confounding variables by providing each condition (game-led and tutor-led) with a similar interactive experience. Both activities shared the same UI, 3D environment and underlying science simulation, with the main differences between conditions being in the delivery of the subject matter.

As the learning activities were closely comparable it is argued that it was the self-determined SPP designed gameplay that created the cognitive difference, as it supported deeper engagement and retention of the subject matter. This argument is not only supported by the higher levels of knowledge retention, but also in the generally higher positive perceptions on Flow conditions found in the game-led results of both Ora and Geo.

# 9

## Conclusion

The previous chapter has shown how the research question and hypotheses were evaluated under the two research streams; a) The design process, and b) Structured learning activities. The streams were derived from a breakdown of the research question: ***“What is an effective design process for computer games that deliver structured learning activities?”*** The two research streams should not be considered independently of each other, as the ‘structured learning activities’ are dependent on careful implementation of the design process.

The hypothesis of this research states that: ***H<sub>1</sub>: The Structural Playability Process of educational game design acts as an effective design approach for delivering structured learning activities.*** Chapters 4 to 7 detailed the design and development of the two game projects; *“GeoThermal World”* and *“Ora – Save the Forest!”*.

**Under stream a); Design process, it was found that:**

- It is the connecting Spaces of the SPP that provided the structural support for the games’ practical design and development. It is through the SPP ‘Spaces’ that educational values, intended from the outset, are tracked and delivered inside the gameplay experience. The learning outcomes and objectives are the connecting factors to the gameplay goals, and how they are then translated and mapped into ‘Missions’ for delivering the learning. Maintaining this structure of links throughout the design and development process establishes the educational worth of the gameplay when it is measured after player interaction.
- When the SPP designed gameplay-led experience was measured against exploratory baseline tutor-led experience it was found, in each instance, that playing the SPP-designed game produced higher overall levels of positive perception on the conditions of Flow and Enjoyment.

Therefore, the use of Skilled Performance as a scaffolding process, in conjunction with motivation theories and learning outcomes, provides a sound basis for gameplay development when applied in the SPP approach.

**Under stream b); Structured learning activities, it was found that:**

- Result outcomes were consistent across each game project. From pre- to post-test players had a significant increase in their subject knowledge.
- The SPP provided learning outcome results that were as good as the tutor-led learning experience. No significant difference was found between scores for the SPP game-led experiences and the traditional tutor-led experiences.
- In addition, the Ora game-led participants, when tested again after a four week interval, showed significantly higher levels of knowledge retention from pre-test levels. In comparison, participants in the tutor-led experience returned to a level that was no longer significant from their pre-test levels.

Therefore, the outcomes of two game projects (*sections 8.4 & 8.5*), support  $H_1$ , that the Structural Playability Process of educational game design acts as an effective design approach for delivering structured learning activities.

The SPP designed games delivered consistent outcomes on positive perceptions of Flow conditions and levels of knowledge acquisition across the two game projects. Although there were small variations, in the detail of the outcomes, as would be expected with two such different game concepts. It is proposed that the Structural Playability Process proved to be a reliable method for the practical design and development of educational games.

## **9.1 Lessons Learned**

This section highlights the key lessons learned from the implementation of the Structural Playability Process, as a practical approach for the design of educational gameplay and game development.

### **9.1.1 General Observations**

- Game production projects involve many factors; from project managing a development team and generating assets and content, to implementing last minute client changes. The variables of budget, time and gaining a clear understanding of the educational issues to be implemented can

have a considerable impact on production. This may subsequently impact the gameplay experience and educational outcomes. The SPP does not make game projects immune to the impacts of such outside variables however it does provide a practical way of structuring design and development.

- The adapted EGameFlow questionnaire provided a validated method for assessing Flow in the user studies. It is felt that this could be adapted further to more strongly reflect all the conditions of a Flow state. This would work well for assessing the value of gameplay designed using the SPP approach, and for those looking to assess any educational game for its Flow levels.

### 9.1.2 Observations on the SPP Approach

- To make the SPP most effective the game-designer will need an understanding of the Skilled Performance aspects of gameplay design, as outlined in the SPD. This is most relevant when creating the Skill Stages that sit between the Design and Engine spaces of the SPP. A recommendation for further development of the SPP would be to expand the Skill Stages of the SPP to fully reference the Skill Stage section of the SPD.
- The Design and Engine Spaces are practical, straightforward and general enough to be applied to any serious game concept. However, considerable collaboration is required by designer and client to work through the Educational and Translation Spaces. For a game designer not well versed in academic teaching methods, the mapping of learning outcomes could prove challenging.

## 9.2 Contributions

In general, the findings of this thesis contribute new knowledge by reporting on the outcomes of two computer games designed using the Structural Playability Process (SPP) of educational game design.

The main contributions of this research are in bringing a new and generalizable model of educational game design to the field of serious games. This model and process not only build upon valid learning theories but also addresses the complexities of practical implementation. Other game design models in the educational technology field show a tendency to concentrate on the theories of educational game design. Whereas, in contrast the SPP applies its theories in clear practical steps for implementation. This is seen in the four Spaces that form its structure and code-base for the in-engine mission system.

- The SPP divides the design of a game project into spaces that simplify and structure, the complexity of a game project. This provides the method for linking learning outcomes to gameplay missions. The SPP Spaces are practical, straightforward, and general enough to be applied to any serious game concept.
- The SPP method also contributes a code-based mission system that is replicable in the Unity game engine for any gameplay design. This code creates an in-engine editor interface, known as the Mission System, used by the designer to structure and tweak player experiences. This hands more control to the designer relieving the coder from application of design issues.

The second of the main contributions lies in the comparison of how the SPP design approach was able to be applied across two games projects. This shows that the SPP can be generalised to support different games designs whilst providing consistent outcomes.

Additionally, the findings provide a contribution to the understanding of designing for motivation; as indicated through the analysis of flow levels and how game design can support knowledge acquisition contributing empirical evidence on the effectiveness of games as learning environments.

- The trends revealed in the review of literature revealed that games stimulate motivation, skill development and affect learning (Aguilera & Méndiz, 2003; Boyle, et al., 2011; Connolly et al., 2012; Dondlinger, 2007). The two SPP structured game projects contribute valuable results to an understanding of how design can lead to the emergence of intrinsic-motivation and skill development (Keller & Bless, 2008). This advances game design methods by 'designing-in' conditions that directly support a players' motivation to achieve goals. The designing-in was achieved by applying Skilled Performance (Fitts & Posner, 1967) as the scaffolding theory upon which the gameplay structures were built. From the links between Flow conditions, Skilled Performance plus the results of the EGameFlow measure, it can be inferred that this method provided a platform for the occurrence of Flow conditions. (Csikszentmihalyi, 1990; Fu et al., 2009; Sweetser & Wyeth, 2005).
- The research outcomes provide support to the assertion that games can impact knowledge acquisition/content understanding and motivational outcomes (Connolly, et al., 2012). The findings from each game display the impact games can have on knowledge acquisition, as results showed a significant increase in learning gains from pre/post levels and a significant level of knowledge retention, as experienced by the Ora game-led players.



- Further research contributions to the field address criticisms put forward by O’Neil, et al. (2005) who stated; ‘evidence of potential [in games] is striking, but the empirical evidence for effectiveness of games as learning environments is scant’. This research details the start-to-finish process of the two SPP designed game projects, and their subsequent analysis. The SPP contributes new empirical evidence towards the effectiveness of games and learning environments. It allows for the measurement of clearly set learning outcomes, which are tracked throughout the design and development process and reflected in the positive levels of knowledge acquisition found.

Finally, this research contributes two serious games to the field: *GeoThermal World* and *Ora – Save the Forest!*

- *GeoThermal World* augments the standard field-trip experience by providing a virtual landscape for geothermal exploration that is currently being used by Geology students’ prior to their real geothermal field-trip experience.
- *Ora – Save the Forest!* contributes by translating the complex scientific modelling of pest species interactions within native forests into a gameplay experience. Making the science accessible for non-scientists while acting as a conduit for knowledge transfer between the stakeholders. This game has a proposed release date to the public in the latter half of 2014.

Overall, the findings of this research suggest that the SPP has the potential to be a powerful tool for educational game design.

### **9.3 Future Work**

There are a number of areas of future research and activities that could be continued following this thesis. These include:

- 1/ Dissemination – teaching the SPP process
- 2/ Comparative Evaluation – comparing SPP to other educational design processes
- 3/ Metrics – use captured gameplay metrics (i.e. from within the game engine) for more detailed analysis
- 4/ Ora Game Completion – complete the development of the Ora game
- 5/ Evaluation Tools – better evaluation tools that probe the cognitive and skill based processes of the players.

## 1. Dissemination

The fact that both games were designed by one person fulfilling the roles of both designer and researcher has to be noted as a limiting factor. Future opportunities for further dissemination and testing of the SPP could be achieved through game design workshops or game-jams, in collaboration with other game designers and their unique projects. There is a network of Global Game Jams<sup>10</sup>, termed as a “hackathon focused on game development”, where the SPP could be tested under pressure during a “condensed... 48 hour development cycle”. Dissemination in this manner provides the opportunity of being able to successfully teach the SPP process to others and have it guide the development of dozens of games.

There is also the opportunity for dissemination through conference workshops. There are several serious game focused conferences that would provide this opportunity. These are the annual ‘Games 4 Change’ festival<sup>11</sup> and the Serious Games Association<sup>12</sup> annual conference, with other large scale events such as the Game Developers Conference<sup>13</sup> (GDC) global network targeting entertainment-based gaming.

Before the SPP could be taken to such events and used by independent designers and developers a user guide detailing the steps to be taken in each of the SPP ‘Spaces’ will need to be developed. This would outline the steps to be taken in each of the ‘Spaces’, which would include an overview of the supporting learning theories. This can be produced in an eBook format and made available as a downloadable teaching resource.

## 2. Comparative Evaluation

It would prove useful to not only develop more games using the SPP with other designers, but to also compare the SPP with different design methods. The SPP presents a new method of design in its use of skilled performance theory (Fitts & Posner, 1967). However, as skilled performance conditions share commonalities with Flow, it should be possible to compare the SPP to other flow-based models, such as; Kiili's (2005) Experiential gaming model, or Cowley's (2008) USE model for virtual interactive entertainment. By following an experimental design, each game under development would focus the

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<sup>10</sup> <http://globalgamejam.org/>

<sup>11</sup> <http://www.gamesforchange.org/>

<sup>12</sup> <http://www.seriousgamesassociation.com/>

<sup>13</sup> <http://www.gdconf.com/>

gameplay to meet the same ‘complex problem’, and in this way the outcomes under test would reveal the value of the respective methodologies.

### 3. Metrics

At the very end of the SPP flow diagram is a section for metrics. Metrics describes the data that can be collected from the unique gameplay experience of each player. It should be noted that these are objective data acquired non-intrusively from within the workings of the game engine. These log files can be used for a range of analyses, from the generation of heat maps to player decision patterns. Both of the SPP designed games were programmed to collect the data from players. In future work planned by the author, the log-analysis tools will be developed so that knowledge acquisition and Flow scores can be analysed against player strategies and interactions. For example:

- In the analysis of Flow conditions, players who responded with a positive level of challenge in the post-play questionnaire could be analysed against their playing strategies during gameplay. This would reveal if high or low Flow scores corresponded to particular playing patterns.
- In addition it would be interesting to see if participants who had high scoring skills tests had the same metrics patterns as those with low/average scores.
- Or we can also look association between strong immersion results and time on task.

### 4. Ora Game Completion

In addition to further development of the SPP approach to gameplay, the Ora game itself is still in a prototype stage and requires a redesign based on the outcomes of its user study. This game will continue to be developed in collaboration with Landcare Research under their program of community engagement. The intention is for ‘Ora’ to be released online as a web browser game towards the end of 2014.

Further work required for Ora includes:

- The integration of an in-game save and load system capable of re-instantiating the forest timeline that carries a player’s unique set of scientific modelling data.
- Redesign of the user interface to simplify the interactions with the science model in the gameplay world.
- Integration of the remaining skill stages; 2 to 4, and the missions required to meet them.

- Making the game available online either through a dedicated entertainment based gaming portal such as Steam<sup>14</sup>, or through online hosting through a web browser such as Google Chrome web store<sup>15</sup>.

## 5. Evaluation Tools

Another area for future work would be to continue to explore better evaluation methods to support the need for more empirical data following the experimental method. This could take the form of building upon the work of Sweetser & Wyeth, (2005) GameFlow evaluation model and Fu et al., (2009) EGameFlow questionnaire, while also examining the usefulness of Wiebe's et al., (2014) User Engagement Scale (UES) for Flow assessment. With more focused evaluation tools future studies may be able to tease apart the degrees of difference an SPP designed game brings in comparison to other, different gaming experience.

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<sup>14</sup> <http://store.steampowered.com/about/>

<sup>15</sup> <https://chrome.google.com/webstore/category/app/3-games>

## References

- Aguilera, M. D. E., & Méndiz, A. (2003). Video Games and Education: (Education in the Face of a “Parallel School”). *Computers in Entertainment (CIE)*, 1(1), 1–14.
- Allan, J. (1996). Learning outcomes in higher education. *Studies in Higher Education*, 21(1), 93–108. doi:10.1080/03075079612331381487
- Allan, J. (2006). Learning Outcomes in Higher Education. *Studies in Higher Education*, (January 2013), 37–41.
- Amory, A. (2006). Game object model version II: a theoretical framework for educational game development. *Educational Technology Research and Development*, 55(1), 51–77. doi:10.1007/s11423-006-9001-x
- Annetta, L. a., Minogue, J., Holmes, S. Y., & Cheng, M.-T. (2009). Investigating the impact of video games on high school students’ engagement and learning about genetics. *Computers & Education*, 53(1), 74–85. doi:10.1016/j.compedu.2008.12.020
- Arnab, S., Lim, T., Carvalho, M. B., Bellotti, F., de Freitas, S., Louchart, S., ... De Gloria, A. (2014). Mapping learning and game mechanics for serious games analysis. *British Journal of Educational Technology*, n/a–n/a. doi:10.1111/bjet.12113
- Ball, S. J., Ramsey, D., Nugent, G., Warburton, B., & Efford, M. (2005). A method for estimating wildlife detection probabilities in relation to home-range use: insights from a field study on the common brushtail possum ( *Trichosurus vulpecula* ). *Wildlife Research*, 32(3), 217. doi:10.1071/WR03125
- Bangor, A., Kortum, P. T., & Miller, J. T. (2008). An Empirical Evaluation of the System Usability Scale. *International Journal of Human-Computer Interaction*, 24(6), 574–594. doi:10.1080/10447310802205776
- Baranowski, T., Buday, R., Thompson, D. I., & Baranowski, J. (2008). Playing for real: video games and stories for health-related behavior change. *American Journal of Preventive Medicine*, 34(1), 74–82. doi:10.1016/j.amepre.2007.09.027
- Barthes, R., & Duisit, L. (1975). An Introduction to the Structural of Analysis Narrative. *New Literary History*, 6(2), 237–272. doi:10.2307/468419
- Beaunieux, H., Hubert, V., Witkowski, T., Pitel, A.-L., Rossi, S., Danion, J.-M., ... Eustache, F. (2006). Which processes are involved in cognitive procedural learning? *Memory (Hove, England)*, 14(5), 521–39. doi:10.1080/09658210500477766
- Bellotti, F., Kapralos, B., Lee, K., Moreno-Ger, P., & Berta, R. (2013). Assessment in and of Serious Games: An Overview. *Advances in Human-Computer Interaction*, 2013, 1–11. doi:10.1155/2013/136864

- Biggs, J. (2003). Formulating and clarifying curriculum objectives. In *Teaching for Quality Learning at University* (2nd ed., pp. 34–55). Buckingham: Open University Press.
- Biggs, J. B., & Collis, K. F. (1982). *Evaluating the quality of learning*. New York: ACADEMIC PRESS.
- Bloomfield, J., Roberts, J., & While, A. (2010). The effect of computer-assisted learning versus conventional teaching methods on the acquisition and retention of handwashing theory and skills in pre-qualification nursing students: a randomised controlled trial. *International Journal of Nursing Studies*, 47(3), 287–94. doi:10.1016/j.ijnurstu.2009.08.003
- Boyle, E., Connolly, T. M., & Hainey, T. (2011). The role of psychology in understanding the impact of computer games. *Entertainment Computing*, 2(2), 69–74. doi:10.1016/j.entcom.2010.12.002
- Bradshaw, H. (2004). Playschool, What is “ Playability ” and Why Do We Need It ? *Develop*, 1.
- Bradshaw, H. (2007). Computer Game Playability – Learning Through Gameplay Design. In M. Taisch (Ed.), *2nd International Learning with Games Conference*. Sophia Antipolis, France. Retrieved from [http://www.hazelbradshaw.co.uk/downloads/Learning\\_Gameplay\\_Design.pdf](http://www.hazelbradshaw.co.uk/downloads/Learning_Gameplay_Design.pdf)
- Bradshaw, H. (2010). Entertainment Education For The Computer Age : Investigating The Engaging Nature Of Computer Games For Educational Application. In *ICERI2010 Conference* (pp. 3772–3781). Madrid, Spain.
- Brooke, J. (1996). SUS - A quick and dirty usability scale. In P. W. Jordan, B. Thomas, B. A. Weerdmeester, & I. L. McClelland (Eds.), *Usability evaluation in industry* (pp. 189–194). London.
- Bruckman, A. (1999). Can educational be fun? In *Game developers conference* (pp. 75–79).
- Chan, C. (2009). Assessment: Short Answer Questions. Retrieved March 19, 2014, from <http://ar.cetl.hku.hk>
- Chittaro, L. (2012). Passengers’ Safety in Aircraft Evacuations: Employing Serious Games to Educate and Persuade. *Persuasive Technology. Design for Health and Safety*, 7284, 215–226. Retrieved from [http://link.springer.com/chapter/10.1007/978-3-642-31037-9\\_19](http://link.springer.com/chapter/10.1007/978-3-642-31037-9_19)
- Connolly, T. M., Boyle, E. A., Macarthur, E., Hainey, T., & Boyle, J. M. (2012). A systematic literature review of empirical evidence on computer games and serious games. *Computers & Education*, 59(2), 661–686. doi:10.1016/j.compedu.2012.03.004
- Cooper, S., Khatib, F., Treuille, A., Barbero, J., Lee, J., Beenen, M., ... Players, F. (2010). Predicting protein structures with a multiplayer online game. *Nature*, 466(7307), 756–60. doi:10.1038/nature09304
- Coplan, A. (2004). Empathic Engagement with Narrative Fictions. *The Journal of Aesthetics and Art Criticism*, 62(2), 141–152.
- Cowley, B., Charles, D., Black, M., & Hickey, R. (2006). User-System-Experience Model for User Centered Design in Computer Games, 419–424.
- Cowley, B., Charles, D., Black, M., & Ireland, N. (2008). Toward an Understanding of Flow in Video Games. *Computers in Entertainment*, 6(2), 1–27.

- Csikszentmihalyi, M. (1990). *FLOW : The Psychology of Optimal Experience*. Harper and Row.
- Csikszentmihalyi, M. (1997). *Finding flow: The psychology of engagement with everyday life*. Basic Books.
- De Freitas, S., & Oliver, M. (2006). How can exploratory learning with games and simulations within the curriculum be most effectively evaluated? *Computers & Education*, 46(3), 249–264. doi:10.1016/j.compedu.2005.11.007
- Deci, E., & Ryan, R. (1985). *Intrinsic Motivation and Self-Determination in Human Behavior*. (E. Aronson, Ed.) (pp. 1–5 28–40). New York: Plenum Press. Retrieved from <http://ipac.canterbury.ac.nz/ipac20/ipac.jsp?index=BIB&term=192380>
- Ding, S., Tang, N., Lin, T., & Zhao, S. (2009). RTS-GameFlow: A New Evaluation Framework for RTS Games. In *2009 International Conference on Computational Intelligence and Software Engineering* (pp. 1–4). Ieee. doi:10.1109/CISE.2009.5363526
- Dohaney, J., Brogt, E., & Kennedy, B. (2014). Field Note-taking Behaviour and Perceptions: Towards Classification and Best Practices (in review). *Journal of Geoscience Education*.
- Dohaney, J., Kennedy, B., Brogt, E., & Bradshaw, H. (2012). The Geothermal World Videogame : An Authentic , Immersive Videogame Used To Teach Observation Skills Needed For Exploration. In *New Zealand Geothermal Workshop*. Auckland, New Zealand: International Geothermal Association. Retrieved from [http://www.geothermal-energy.org/publications\\_and\\_services/conference\\_paper\\_database.html](http://www.geothermal-energy.org/publications_and_services/conference_paper_database.html)
- Dondlinger, M. J. (2007). Educational Video Game Design : A Review of the Literature. *Applied Educational Technology*, 4(1), 21–31.
- Dunwell, I., Petridis, P., Hendrix, M., Arnab, S., AL-Smadi, M., & Guetl, C. (2012). Guiding Intuitive Learning in Serious Games: An Achievement-Based Approach to Externalized Feedback and Assessment. *2012 Sixth International Conference on Complex, Intelligent, and Software Intensive Systems*, 911–916. doi:10.1109/CISIS.2012.205
- Edmondson, D. R., Boyer, S. L., & Artis, A. B. (2012). SELF-DIRECTED LEARNING : A META-ANALYTIC REVIEW OF ADULT LEARNING CONSTRUCTS. *International Journal of Education Research*, 7(1), 40–48.
- Egenfeldt-Nielsen, S. (2007). Third Generation Educational Use of Computer Games. *Educational Multimedia and Hypermedia*, 16(3), 263–281.
- Finneran, C. M., & Zhang, P. (2003). A person–artefact–task (PAT) model of flow antecedents in computer-mediated environments. *International Journal of Human-Computer Studies*, 59(4), 475–496. doi:10.1016/S1071-5819(03)00112-5
- Finneran, C. Zhang, P. (2003). A Person-Artifact-Task ( PAT ) Model of Flow Antecedents in Computer-Mediated Environments. *International Journal of Human-Computer Studies*, 1–30.
- Fitts, P. M., & Posner, M. I. (1967). Human Performance. In *Human Performance*. Belmont, Calif: Brooks/Cole Pub. Co.

- Fu, F.-L., Su, R.-C., & Yu, S.-C. (2009). EGameFlow: A scale to measure learners' enjoyment of e-learning games. *Computers & Education*, 52(1), 101–112. doi:10.1016/j.compedu.2008.07.004
- Galarneau, L. (2014). 2014 Global Gaming Stats: Who's Playing What, and Why? Retrieved May 18, 2014, from <http://www.bigfishgames.com/blog/2014-global-gaming-stats-whos-playing-what-and-why/>
- Garris, R., Ahlers, R., & Driskell, J. E. (2002). Games, Motivation, and Learning: A Research and Practice Model. *Simulation & Gaming*, 33(4), 441–467. doi:10.1177/1046878102238607
- Girard, C., Ecalle, J., & Magnan, a. (2013). Serious games as new educational tools: how effective are they? A meta-analysis of recent studies. *Journal of Computer Assisted Learning*, 29(3), 207–219. doi:10.1111/j.1365-2729.2012.00489.x
- Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, 66(1), 64. doi:10.1119/1.18809
- Holland, E. P., Pech, R. P., Ruscoe, W. A., Parkes, J. P., Nugent, G., & Duncan, R. P. (2013). Thresholds in plant-herbivore interactions: predicting plant mortality due to herbivore browse damage. *Oecologia*, 172(3), 751–66. doi:10.1007/s00442-012-2523-5
- Hong, J.-C., Cheng, C.-L., Hwang, M.-Y., Lee, C.-K., & Chang, H.-Y. (2009). Assessing the educational values of digital games. *Journal of Computer Assisted Learning*, 25(5), 423–437. doi:10.1111/j.1365-2729.2009.00319.x
- Hunicke, R., Leblanc, M., & Zubek, R. (2004). MDA: A Formal Approach to Game Design and Game Research. In *AAAI Workshop on Challenges in Game AI* (pp. 04–04).
- Jackson, S. A., & Marsh, H. W. (1996). Development and Validation of a Scale to Measure Optimal Experience : The Flow State Scale. *JOURNAL OF SPORT & EXERCISE PSYCHOLOGY*, 18, 17–35.
- Jegers, K. (2007). Pervasive Game Flow : Understanding Player Enjoyment in Pervasive Gaming. *Computers in Entertainment*, 5(1), 1–11. doi:10.1145/1219124.1219133
- Jennett, C., Cox, A. L., Cairns, P., Dhoparee, S., Epps, A., Tijs, T., & Walton, A. (2008). Measuring and defining the experience of immersion in games. *International Journal of Human-Computer Studies*, 66(9), 641–661. doi:10.1016/j.ijhcs.2008.04.004
- Kebritchi, M., Hirumi, A., & Bai, H. (2010). The effects of modern mathematics computer games on mathematics achievement and class motivation. *Computers & Education*, 55(2), 427–443. doi:10.1016/j.compedu.2010.02.007
- Keller, J., & Bless, H. (2008). Flow and regulatory compatibility: an experimental approach to the flow model of intrinsic motivation. *Personality & Social Psychology Bulletin*, 34(2), 196–209. doi:10.1177/0146167207310026
- Kelly, T. (2014a). Epic Win. Retrieved March 30, 2014, from <http://www.whatgamesare.com/epic-win.html>



- Kelly, T. (2014b). Sandbox Play. Retrieved March 31, 2014, from <http://www.whatgamesare.com/sandbox-play.html>
- Khatib, F., DiMaio, F., Cooper, S., Kazmierczyk, M., Gilski, M., Krzywda, S., ... Baker, D. (2011). Crystal structure of a monomeric retroviral protease solved by protein folding game players. *Nature Structural & Molecular Biology*, 18(10), 1175–7. doi:10.1038/nsmb.2119
- Kiili, K. (2005). Digital game-based learning: Towards an experiential gaming model. *The Internet and Higher Education*, 8(1), 13–24. doi:10.1016/j.iheduc.2004.12.001
- Kiili, K. (2006). Towards a participatory multimedia learning model. *Educ Inf Technol*, 11, 21–32. doi:10.1007/s10639-005-5711-7
- Kiili, K. (2007). Foundation for problem-based gaming. *British Journal of Educational Technology*, 38(3), 394–404. doi:10.1111/j.1467-8535.2007.00704.x
- Kiili, K. (2010). Power and Flow Experience in Time-Intensive business Simulation Game. *Jl. of Educational Multimedia and Hypermedia*, 19, 39–57.
- Kolb, D. A. (1984). Experiential learning : experience as the source of learning and development. In *Experiential learning: experience as the source of learning and development*. Englewood Cliffs, NJ: Prentice Hall.
- Kooloos, J. G. M., de Waal Malefijt, M. C., Ruiter, D. J., & Vorstenbosch, M. a T. M. (2012). Loosely-guided, self-directed learning versus strictly-guided, station-based learning in gross anatomy laboratory sessions. *Anatomical Sciences Education*, 5(6), 340–6. doi:10.1002/ase.1293
- Krathwohl, D. R. (2002). A Revision of Bloom ' s Taxonomy : An Overview. *Theory into Practice*, 41(4).
- Kühn, S., Gleich, T., Lorenz, R. C., Lindenberger, U., & Gallinat, J. (2014). Playing Super Mario induces structural brain plasticity: gray matter changes resulting from training with a commercial video game. *Molecular Psychiatry*, 19(2), 265–71. doi:10.1038/mp.2013.120
- Linehan, C., Kirman, B., Lawson, S., Chan, G. G., & Lane, J. S. (2011). Practical , Appropriate , Empirically-Validated Guidelines for Designing Educational Games. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 1979–1988).
- Lopez, B. M. (2014). Gameplay Design Fundamentals : Gameplay Progression. Retrieved March 28, 2014, from <http://ubm.io/1mdLykE>
- Maslow, A. H. (1943). A theory of human motivation. *Psychological Review*, 50(4), 370–396. doi:10.1037/h0054346
- Maslow, A. H. (1999). *Towards A Psychology of Being* (3rd ed.). New York: J. Wiley & Son. Retrieved from <http://ipac.canterbury.ac.nz/ipac20/ipac.jsp?index=BIB&term=692116>
- McClarty, K. L., Frey, P. M., & Dolan, R. P. (2012). A Literature Review of Gaming in Education Research Report. *Gaming In Education*, (June).

- McGonigal, J. (2014). We spend 3 billion hours a week as a planet playing videogames. Is it worth it? Retrieved May 18, 2014, from [http://www.ted.com/conversations/44/we\\_spend\\_3\\_billion\\_hours\\_a\\_wee.html](http://www.ted.com/conversations/44/we_spend_3_billion_hours_a_wee.html)
- Miller, A. S. (2003). *Gaia Connections: An Introduction to Ecology, Ecoethics, and Economics* (p. 307). Rowman & Littlefield. Retrieved from <http://books.google.com/books?hl=en&lr=&id=JtzR3nERsk8C&pgis=1>
- Molins-Ruano, P., Sevilla, C., Santini, S., Haya, P. a., Rodríguez, P., & Sacha, G. M. (2014). Designing videogames to improve students' motivation. *Computers in Human Behavior*, 31, 571–579. doi:10.1016/j.chb.2013.06.013
- Newell, A., & Rosenbloom, P. S. (1981). Mechanisms of skill acquisition and the law of practice. *Cognitive Skills and Their Acquisition*, 1.
- O'Neil, H. F., Wainess, R., & Baker, E. L. (2005). Classification of learning outcomes: evidence from the computer games literature. *Curriculum Journal*, 16(4), 455–474. doi:10.1080/09585170500384529
- Oblinger, D. (2006). Simulations, Games, and Learning. *EDUCAUSE*, 39(May), 6. doi:10.1111/j.1467-8535.2007.00725\_2.x
- Prensky, M. (2003). Digital game-based learning. *Computers in Entertainment*, 1(1), 21. doi:10.1145/950566.950596
- Przybylski, A. K., Rigby, C. S., & Ryan, R. M. (2010). A motivational model of video game engagement. *Review of General Psychology*, 14(2), 154–166. doi:10.1037/a0019440
- Ramsey, D. S. L., & Efford, M. G. (2010). Management of bovine tuberculosis in brushtail possums in New Zealand: predictions from a spatially explicit, individual-based model. *Journal of Applied Ecology*, 47(4), 911–919. doi:10.1111/j.1365-2664.2010.01839.x
- Richardson, L. (1990). Narrative and Sociology. *Journal of Contemporary Ethnography*, 19(1), 116–135. doi:10.1177/089124190019001006
- Rossin, D., Ro, Y. K., & Klein, B. D. (2009). The Effects of Flow on Learning Outcomes in an Online Information Management Course. *Journal Of Information Systems Education*, 20(1), 87–98.
- Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *The American Psychologist*, 55(1), 68–78. Retrieved from <http://www.ncbi.nlm.nih.gov/pubmed/11392867>
- Salen, K., & Zimmerman, E. (2004). *Rules of Play: Game Design Fundamentals* (pp. 336–339 350–353 360). Cambridge, Massachusetts: The MIT Press.
- Schell, J. (2008). *The Art of Game Design - A book of Lenses*. Burlington: Morgan Kaufmann Publishers.
- Schmidt, R. A., & Lee, T. (2005). *Motor Control and Learning, A Behavioural Emphasis*. Leeds: Human Kinetics. Retrieved from <http://books.google.com/books?hl=en&lr=&id=vBP091HCz38C&pgis=1>
- Simon, H. A. (1956). Rational Choice and the Structure of the Environment. *Psychological Review*, 63(2), 129–138.

- Spady, W. G. (1984). *Outcome-Based Education: Critical Issues and Answers*. Arlington, Va.: American Association of School Administrators.
- Sullivan, C. O., Cassell, J., Vilhjálmsón, H., Dingliana, J., Dobbyn, S., Mcnamee, B., ... Giang, T. (2002). Levels of Detail for Crowds and Groups ., xx, 1–8.
- Sweetser, P., Johnson, D., Ozdowska, A., & Wyeth, P. (2012). GameFlow heuristics for designing and evaluating real-time strategy games. In *Proceedings of The 8th Australasian Conference on Interactive Entertainment Playing the System - IE '12* (pp. 1–10). Auckland, New Zealand: ACM Press. doi:10.1145/2336727.2336728
- Sweetser, P., & Wyeth, P. (2005). GameFlow: A Model for Evaluating Player Enjoyment in Games. *Computers in Entertainment (CIE)*, 3(3), 1–24.
- Tompkins, D. M., & Ramsey, D. (2007). Optimising bait-station delivery of fertility control agents to brushtail possum populations. *Wildlife Research*, 34(1), 67. doi:10.1071/WR05109
- Turkay, S., Hoffman, D., Kinzer, C. K., Chantes, P., & Vicari, C. (2014). Toward Understanding the Potential of Games for Learning: Learning Theory, Game Design Characteristics, and Situating Video Games in Classrooms. *Computers in the Schools*, 31(1-2), 2–22. doi:10.1080/07380569.2014.890879
- VanLehn, K. (1996). Cognitive skill acquisition. *Annual Review of Psychology*, 47, 513–39. doi:10.1146/annurev.psych.47.1.513
- Vitz, P. C. (1990). The use of stories in moral development. New psychological reasons for an old education method. *The American Psychologist*, 45(6), 709–20. Retrieved from <http://www.ncbi.nlm.nih.gov/pubmed/2195928>
- Wei, T., & Li, Y. (2010). Design of Educational Game : A Literature. In Z. P. et Al (Ed.), *Transactions on Edutainment IV* (LNCS 6250., pp. 266–276).
- Wellington, W. J., & Hutchinson, D. (2010). THE IMPACT OF PLAYING A MARKETING SIMULATION GAME ON PERCEIVED DECISION MAKING ABILITY AMONG INTRODUCTORY MARKETING STUDENTS. *Developments in Business Simulations and Experiential Learning*, 37, 23–32.
- Wiebe, E. N., Lamb, A., Hardy, M., & Sharek, D. (2014). Measuring engagement in video game-based environments: Investigation of the User Engagement Scale. *Computers in Human Behavior*, 32, 123–132. doi:10.1016/j.chb.2013.12.001
- Wouters, P., van Nimwegen, C., van Oostendorp, H., & van der Spek, E. D. (2013). A meta-analysis of the cognitive and motivational effects of serious games. *Journal of Educational Psychology*, 105(2), 249–265. doi:10.1037/a0031311
- Wrzesien, M., & Alcañiz Raya, M. (2010). Learning in serious virtual worlds: Evaluation of learning effectiveness and appeal to students in the E-Junior project. *Computers & Education*, 55(1), 178–187. doi:10.1016/j.compedu.2010.01.003

# Appendix A – The Approach

## A.1 – Skilled Performance and Flow Table

HP Principles - the conditions of a skilled performance	Flow Conditions - the conditions for and of an optimal experience						
	1. A Challenging Activity That Requires Skills	2. The Merging of Action and Awareness	3. Clear Goals and Feedback	4. Concentration on the Task at Hand	5. The Paradox of Control	6. The Loss of Self-Consciousness	7. The Transformation of Time
<b>1. Skilled performance</b> always involves an <b>organized sequence of activities</b>  any capacity to manipulate symbolic information is a "skill"  Any activity contains a bundle of opportunities for action, or "challenges," that require appropriate skills to realize.  For those who don't have the right skills, the activity is not challenging; it is simply meaningless	<b>Optimal experiences are reported to occur within sequences of activities that are goal-directed and bounded by rules</b>  any capacity to manipulate symbolic information is a "skill"  Any activity contains a bundle of opportunities for action, or "challenges," that require appropriate skills to realize.  For those who don't have the right skills, the activity is not challenging; it is simply meaningless	When all a person's relevant skills are needed to cope with the challenges of a situation, that person's attention is completely absorbed by the activity.  All the attention is concentrated on the relevant stimuli.  People become so involved in what they are doing that the activity becomes spontaneous, almost automatic; they stop being aware of themselves as separate from the actions they are performing  "Flow." -Describes well the sense of seemingly effortless movement. -Does not happen without the application of skilled performance. -While it lasts, consciousness works smoothly, action follows action seamlessly. In normal life, we keep interrupting what we do with doubts and questions.  In flow there is no need to reflect, because the action carries us forward	The reason it is possible to achieve such complete involvement in a flow experience is that goals are usually clear, and feedback immediate  Unless a person learns to set goals and to recognize and gauge feedback in such activities, she will not enjoy them.  where goals are not clearly set in advance, a person must develop a strong personal sense of what she intends to do.  The kind of feedback we work toward is in and of itself often unimportant  What makes this information valuable is the symbolic message it contains: that I have succeeded in my goal. Such knowledge creates order in consciousness, and strengthens the structure of the self.  feedback can be enjoyable, provided it is logically related to a goal in which one has invested psychic energy	Enjoyable activities require a complete focusing of attention on the task at hand—thus leaving no room in the mind for irrelevant information.  <b>Flow improves the quality of experience: the clearly structured demands of the activity impose order, and exclude the interference of disorder in consciousness</b>  The concentration of the flow experience—together with clear goals and immediate feedback—provides order to consciousness, inducing the enjoyable condition of psychic neutrality	the flow experience is typically described as involving a sense of control—or, more precisely, as lacking the sense of worry about losing control that is typical in many situations of normal life.  the possibility, rather than the actuality, of control... in principle, in the world of flow perfection is attainable.  This sense of control is also reported in enjoyable activities that involve serious risks, activities that to an outsider would seem to be much more potentially dangerous than the affairs of normal life.  the positive emotion they enjoy is the perfectly healthy feeling of being able to control potentially dangerous forces.  flow experiences, even the seemingly most risky ones, are so constructed as to allow the practitioner to develop sufficient skills to reduce the margin of error to as close to zero as possible.  What people enjoy is not the sense of being in control, but the sense of exercising control in difficult situations. It is not possible to experience a feeling of control unless one is willing to give up the safety of protective routines  This sense of being in a world where entropy is suspended explains in part why flow-producing activities can become so addictive.	One item that disappears from awareness... it is our own Self  The loss of the sense of a self separate from the world around it is sometimes accompanied by a feeling of union with the environment  Preoccupation with the self consumes psychic energy because in everyday life we often feel threatened. Whenever we are threatened we need to bring the image we have of ourselves back into awareness, so we can find out whether or not the threat is serious, and how we should meet it.  <b>In flow there is no room for self-scrutiny. Because enjoyable activities have clear goals, stable rules, and challenges well matched to skills, there is little opportunity for the self to be threatened</b>  <b>This system takes its form from the rules of the activity; its energy comes from the person's attention</b>  This growth of the self occurs only if the interaction is an enjoyable one, that is, if it offers nontrivial opportunities for action and requires a constant perfection of skills	One of the most common descriptions of optimal experience is that time no longer seems to pass the way it ordinarily does. The objective, external duration we measure with reference to outside events is rendered irrelevant by the rhythms dictated by the activity.  During the flow experience the sense of time bears little relation to the passage of time as measured by the absolute convention of the clock. P06  It is not clear whether this dimension of flow is just an epiphenomenon—a by-product of the intense concentration required for the activity at hand—or whether it is something that contributes in its own right to the positive quality of the experience. Losing track of the clock is not one of the major elements of enjoyment p67

Bold text highlights a relevant link and numbers provide a relatedness ranking, with 0/1 = highly related to 5 = somewhat related

2. Skilled behaviour is goal directed	Flow Conditions - the conditions for and of an optimal experience						
	1. A Challenging Activity That Requires Skills	2. The Merging of Action and Awareness	3. Clear Goals and Feedback	4. Concentration on the Task at Hand	5. The Paradox of Control	6. The Loss of Self-Consciousness	7. The Transformation of Time
<b>2. Skilled behaviour is goal directed</b>  any capacity to manipulate symbolic information is a "skill"  Any activity contains a bundle of opportunities for action, or "challenges," that require appropriate skills to realize.  For those who don't have the right skills, the activity is not challenging; it is simply meaningless	<b>Optimal experiences are reported to occur within sequences of activities that are goal-directed and bounded by rules</b>  any capacity to manipulate symbolic information is a "skill"  Any activity contains a bundle of opportunities for action, or "challenges," that require appropriate skills to realize.  For those who don't have the right skills, the activity is not challenging; it is simply meaningless	When all a person's relevant skills are needed to cope with the challenges of a situation, that person's attention is completely absorbed by the activity.  All the attention is concentrated on the relevant stimuli.  People become so involved in what they are doing that the activity becomes spontaneous, almost automatic; they stop being aware of themselves as separate from the actions they are performing  "Flow." -Describes well the sense of seemingly effortless movement. -Does not happen without the application of skilled performance. -While it lasts, consciousness works smoothly, action follows action seamlessly. In normal life, we keep interrupting what we do with doubts and questions.  In flow there is no need to reflect, because the action carries us forward	The reason it is possible to achieve such complete involvement in a flow experience is that goals are usually clear, and feedback immediate  Unless a person learns to set goals and to recognize and gauge feedback in such activities, she will not enjoy them.  where goals are not clearly set in advance, a person must develop a strong personal sense of what she intends to do.  The kind of feedback we work toward is in and of itself often unimportant  What makes this information valuable is the symbolic message it contains: that I have succeeded in my goal. Such knowledge creates order in consciousness, and strengthens the structure of the self.  feedback can be enjoyable, provided it is logically related to a goal in which one has invested psychic energy	Enjoyable activities require a complete focusing of attention on the task at hand—thus leaving no room in the mind for irrelevant information.  Flow improves the quality of experience: the clearly structured demands of the activity impose order, and exclude the interference of disorder in consciousness  <b>The concentration of the flow experience—together with clear goals and immediate feedback—provides order to consciousness</b>	the flow experience is typically described as involving a sense of control—or, more precisely, as lacking the sense of worry about losing control that is typical in many situations of normal life.  the possibility, rather than the actuality, of control... in principle, in the world of flow perfection is attainable.  This sense of control is also reported in enjoyable activities that involve serious risks, activities that to an outsider would seem to be much more potentially dangerous than the affairs of normal life.  the positive emotion they enjoy is the perfectly healthy feeling of being able to control potentially dangerous forces.  flow experiences, even the seemingly most risky ones, are so constructed as to allow the practitioner to develop sufficient skills to reduce the margin of error to as close to zero as possible.  What people enjoy is not the sense of being in control, but the sense of exercising control in difficult situations. It is not possible to experience a feeling of control unless one is willing to give up the safety of protective routines  This sense of being in a world where entropy is suspended explains in part why flow-producing activities can become so addictive.	One item that disappears from awareness... it is our own Self  The loss of the sense of a self separate from the world around it is sometimes accompanied by a feeling of union with the environment  Preoccupation with the self consumes psychic energy because in everyday life we often feel threatened. Whenever we are threatened we need to bring the image we have of ourselves back into awareness, so we can find out whether or not the threat is serious, and how we should meet it.  <b>In flow there is no room for self-scrutiny. Because enjoyable activities have clear goals, stable rules, and challenges well matched to skills, there is little opportunity for the self to be threatened</b>  <b>This system takes its form from the rules of the activity; its energy comes from the person's attention</b>  <b>This growth of the self occurs only if the interaction is an enjoyable one, that is, if it offers nontrivial opportunities for action and requires a constant perfection of skills</b>	One of the most common descriptions of optimal experience is that time no longer seems to pass the way it ordinarily does. The objective, external duration we measure with reference to outside events is rendered irrelevant by the rhythms dictated by the activity.  During the flow experience the sense of time bears little relation to the passage of time as measured by the absolute convention of the clock. P06  It is not clear whether this dimension of flow is just an epiphenomenon—a by-product of the intense concentration required for the activity at hand—or whether it is something that contributes in its own right to the positive quality of the experience. Losing track of the clock is not one of the major elements of enjoyment p67

Bold text highlights a relevant link and numbers provide a relatedness ranking, with 0/1 = highly related to 5 = somewhat related

3. The full complexity of sequential activity can seldom be understood except when the end objective or goal is also understood	<p>Optimal experiences are reported to occur within sequences of activities that are goal-directed and bounded by rules</p> <p>any capacity to manipulate symbolic information is a "skill"</p> <p>Any activity contains a bundle of opportunities for action, or "challenges," that require appropriate skills to realise</p> <p>For those who don't have the right skills, the activity is not challenging; it is simply meaningless</p>	<p>When all a person's relevant skills are needed to cope with the challenges of a situation, that person's attention is completely absorbed by the activity.</p> <p>All the attention is concentrated on the relevant stimuli.</p> <p>People become so involved in what they are doing that the activity becomes spontaneous, almost automatic; they stop being aware of themselves as separate from the actions they are performing</p> <p>"flow."</p> <p>-Describes well the sense of seemingly effortless movement.</p> <p>-Does not happen without the application of skilled performance.</p> <p>-While it lasts consciousness works smoothly, action follows action seamlessly. In normal life, we keep interrupting what we do with doubts and questions.</p> <p>in flow there is no need to reflect, because the action carries us forward</p>	<p>The reason it is possible to achieve such complete involvement in a flow experience is that goals are usually clear, and feedback immediate</p> <p>Unless a person learns to set goals and to recognize and gauge feedback in such activities, she will not enjoy them</p> <p>where goals are not clearly set in advance, a person must develop a strong personal sense of what she intends to do</p> <p>The kind of feedback we work toward is in and of itself often unimportant</p> <p>What makes this information valuable is the symbolic message it contains: that I have succeeded in my goal. Such knowledge creates order in consciousness, and strengthens the structure of the self.</p> <p>feedback can be enjoyable, provided it is logically related to a goal in which one has invested psychic energy</p>	<p>Enjoyable activities require a complete focusing of attention on the task at hand—thus leaving no room in the mind for irrelevant information</p> <p>flow improves the quality of experience: the clearly structured demands of the activity impose order, and exclude the interference of disorder in consciousness</p> <p>The concentration of the flow experience—together with clear goals and immediate feedback—provides order to consciousness</p>	<p>the flow experience is typically described as involving a sense of control—or, more precisely, as lacking the sense of worry about losing control that is typical in many situations of normal life.</p> <p>the possibility, rather than the actuality, of control... in principle, in the world of flow perfection is attainable.</p> <p>This sense of control is also reported in enjoyable activities that involve serious risks, activities that to an outsider would seem to be much more potentially dangerous than the affairs of normal life.</p> <p>the positive emotion they enjoy is the perfectly healthy feeling of being able to control potentially dangerous forces.</p> <p>flow experiences, even the seemingly most risky ones, are so constructed as to allow the practitioner to develop sufficient skills to reduce the margin of error to as close to zero as possible.</p> <p>What people enjoy is not the sense of being in control, but the sense of exercising control in difficult situations. It is not possible to experience a feeling of control unless one is willing to give up the safety of protective routines</p> <p>This sense of being in a world where entropy is suspended explains in part why flow-producing activities can become so addictive.</p>	<p>One item that disappears from awareness... it is our own Self</p> <p>The loss of the sense of a self separate from the world around it is sometimes accompanied by a feeling of union with the environment</p> <p>Preoccupation with the self consumes psychic energy because in everyday life we often feel threatened. Whenever we are threatened we need to bring the image we have of ourselves back into awareness, so we can find out whether or not the threat is serious, and how we should meet it.</p> <p>In flow there is no room for self-scrutiny. Because enjoyable activities—have dear goals, stable rules, and challenges well matched to skills, there is little opportunity for the self to be threatened</p> <p>This system takes its form from the rules of the activity; its energy comes from the person's attention</p> <p>An enjoyable activity offers nontrivial opportunities for action and requires a constant perfection of skills</p>	<p>One of the most common descriptions of optimal experience is that time no longer seems to pass the way it ordinarily does. The objective, external duration we measure with reference to outside events is rendered irrelevant by the rhythms dictated by the activity.</p> <p>During the flow experience the sense of time bears little relation to the passage of time as measured by the absolute convention of the clock. 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**Bold text highlights a relevant link and numbers provide a relatedness ranking, with 0/1 = highly related to 5 = somewhat related**

4. Each act is dependent upon comparison of what they think is desired, either through feedback (external stimuli) or comparison of progress towards a goal.	<p>Optimal experiences are reported to occur within sequences of activities that are goal-directed and bounded by rules</p> <p>any capacity to manipulate symbolic information is a "skill"</p> <p>Any activity contains a bundle of opportunities for action, or "challenges," that require appropriate skills to realize.</p> <p>For those who don't have the right skills, the activity is not challenging; it is simply meaningless</p>	<p>When all a person's relevant skills are needed to cope with the challenges of a situation, that person's attention is completely absorbed by the activity.</p> <p>All the attention is concentrated on the relevant stimuli.</p> <p>People become so involved in what they are doing that the activity becomes spontaneous, almost automatic; they stop being aware of themselves as separate from the actions they are performing</p> <p>"flow."</p> <p>-Describes well the sense of seemingly effortless movement.</p> <p>-Does not happen without the application of skilled performance.</p> <p>-While it lasts consciousness works smoothly, action follows action seamlessly. In normal life, we keep interrupting what we do with doubts and questions.</p> <p>in flow there is no need to reflect, because the action carries us forward</p>	<p>The reason it is possible to achieve such complete involvement in a flow experience is that goals are usually clear, and feedback immediate</p> <p>Unless a person learns to set goals and to recognize and gauge feedback in such activities, she will not enjoy them.</p> <p>where goals are not clearly set in advance, a person must develop a strong personal sense of what she intends to do</p> <p>The kind of feedback we work toward is in and of itself often unimportant. –</p> <p>What makes this information valuable is the symbolic message it contains: that I have succeeded in my goal. Such knowledge creates order in consciousness, and strengthens the structure of the self</p> <p>feedback can be enjoyable, provided it is logically related to a goal in which one has invested psychic energy</p>	<p>Enjoyable activities require a complete focusing of attention on the task at hand—thus leaving no room in the mind for irrelevant information</p> <p>flow improves the quality of experience: the clearly structured demands of the activity impose order, and exclude the interference of disorder in consciousness</p> <p>The concentration of the flow experience—together with clear goals and immediate feedback—provides order to consciousness</p>	<p>the flow experience is typically described as involving a sense of control—or, more precisely, as lacking the sense of worry about losing control that is typical in many situations of normal life.</p> <p>the possibility, rather than the actuality, of control... in principle, in the world of flow perfection is attainable.</p> <p>This sense of control is also reported in enjoyable activities that involve serious risks, activities that to an outsider would seem to be much more potentially dangerous than the affairs of normal life.</p> <p>the positive emotion they enjoy is the perfectly healthy feeling of being able to control potentially dangerous forces.</p> <p>flow experiences, even the seemingly most risky ones, are so constructed as to allow the practitioner to develop sufficient skills to reduce the margin of error to as close to zero as possible.</p> <p>What people enjoy is not the sense of being in control, but the sense of exercising control in difficult situations. It is not possible to experience a feeling of control unless one is willing to give up the safety of protective routines</p> <p>This sense of being in a world where entropy is suspended explains in part why flow-producing activities can become so addictive.</p>	<p>One item that disappears from awareness... it is our own Self</p> <p>The loss of the sense of a self separate from the world around it is sometimes accompanied by a feeling of union with the environment</p> <p>Preoccupation with the self consumes psychic energy because in everyday life we often feel threatened. Whenever we are threatened we need to bring the image we have of ourselves back into awareness, so we can find out whether or not the threat is serious, and how we should meet it.</p> <p>In flow there is no room for self-scrutiny. Because enjoyable activities—have dear goals, stable rules, and challenges well matched to skills, there is little opportunity for the self to be threatened</p> <p>This system takes its form from the rules of the activity; its energy comes from the person's attention</p> <p>An enjoyable activity offers nontrivial opportunities for action and requires a constant perfection of skills</p>	<p>One of the most common descriptions of optimal experience is that time no longer seems to pass the way it ordinarily does. The objective, external duration we measure with reference to outside events is rendered irrelevant by the rhythms dictated by the activity.</p> <p>During the flow experience the sense of time bears little relation to the passage of time as measured by the absolute convention of the clock. 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HP Skill Phases - the stages of skill learning	Flow Conditions - the conditions for and of an optimal experience						
	1. A Challenging Activity That Requires Skills	2. The Merging of Action and Awareness	3. Clear Goals and Feedback	4. Concentration on the Task at Hand	5. The Paradox of Control	6. The Loss of Self-Consciousness	7. The Transformation of Time
<b>1. Early or Cognitive Phase</b>  This is when a learner tries to understand the task and what is being demanded of them  A good instructor calls attention to the perceptual cues, response characteristics & gives diagnostic knowledge of results.  Behaviour can be shaped by affirming sequences of acts that resemble the correct one (positive feedback)  In the early stages of skill learning the player needs to attend to cues, events & responses that later go un-noticed.  In this early stage instructions and demonstrations are most effective in the development of the activity.	Optimal experiences are reported to occur within sequences of activities that are goal-directed and bounded by rules  Any activity contains a bundle of opportunities for action, or "challenges," that require appropriate skills to realize.  For those who don't have the right skills, the activity is not challenging; it is simply meaningless	When all a person's relevant skills are needed to cope with the challenges of a situation, that person's attention is completely absorbed by the activity.  All the attention is concentrated on the relevant stimuli.  People become so involved in what they are doing that the activity becomes spontaneous, almost automatic; they stop being aware of themselves as separate from the actions they are performing  "Flow." -Describes well the sense of seemingly effortless movement. -Does not happen without the application of skilled performance. -While it lasts consciousness works smoothly, action follows action seamlessly. In normal life, we keep interrupting what we do with doubts and questions.  in flow there is no need to reflect, because the action carries us forward	The reason it is possible to achieve such complete involvement in a flow experience is that goals are usually clear, and feedback immediate  Unless a person learns to set goals and to recognize and gauge feedback in such activities, she will not enjoy them.  where goals are not clearly set in advance, a person must develop a strong personal sense of what she intends to do  The kind of feedback we work toward is in and of itself often unimportant. - Feedback: What makes this information valuable is the symbolic message it contains: that I have succeeded in my goal. Such knowledge creates order in consciousness, and strengthens the structure of the self.  feedback can be enjoyable, provided it is logically related to a goal in which one has invested psychic energy	Enjoyable activities require a complete focusing of attention on the task at hand thus leaving no room in the mind for irrelevant information  Flow improves the quality of experience: the clearly structured demands of the activity impose order, and exclude the interference of disorder in consciousness  The concentration of the flow experience together with clear goals and immediate feedback-provides order to consciousness, inducing the enjoyable condition of psychic negentropy	the flow experience is typically described as involving a sense of control—or, more precisely, as lacking the sense of worry about losing control that is typical in many situations of normal life.  the possibility, rather than the actuality, of control... in principle, in the world of flow perfection is attainable.  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One item that disappears from awareness... it is our own Self  The loss of the sense of a self separate from the world around it is sometimes accompanied by a feeling of union with the environment  Preoccupation with the self consumes psychic energy because in everyday life we often feel threatened. Whenever we are threatened we need to bring the image we have of ourselves back into awareness, so we can find out whether or not the threat is serious, and how we should meet it.  In flow there is no room for self-scrutiny. Because enjoyable activities have clear goals, stable rules, and challenges well matched to skills, there is little opportunity for the self to be threatened  This growth of the self occurs only if the interaction is an enjoyable one, that is, if it offers nontrivial opportunities for action and requires a constant perfection of skills  An enjoyable activity offers nontrivial opportunities for action and requires a constant perfection of skills	One of the most common descriptions of optimal experience is that time no longer seems to pass the way it ordinarily does. The objective, external duration we measure with reference to outside events is rendered irrelevant by the rhythms dictated by the activity.  During the flow experience the sense of time bears little relation to the passage of time as measured by the absolute convention of the clock. 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	1		4			4	4

Bold text highlights a relevant link and numbers provide a relatedness ranking, with 0/1 = highly related to 5 = somewhat related

<b>2. Intermediate or Associative Phase</b>  New patterns of skill are utilised that are based on the skills learnt in the cognitive phase. In this phase you should be showing a marked reduction in large mistakes.  Frequent repetition within short periods of time results in greater depression in performance  Possibly from decreasing motivation, which accompanies continuous performance of a skill  Frequent rest periods will facilitate performance especially in motor skills as lack of muscle rest creates incorrect practice as muscles tire.  Skill learning in this Phase 1. If the skill components are independent of each other practise each separately 2. If the task can't be done independently then learn it as a whole, but if the task is too complex to practise as a whole then practice it in its separate independent components.	Optimal experiences are reported to occur within sequences of activities that are goal-directed and bounded by rules  Any activity contains a bundle of opportunities for action, or "challenges," that require appropriate skills to realize.  For those who don't have the right skills, the activity is not challenging; it is simply meaningless	When all a person's relevant skills are needed to cope with the challenges of a situation, that person's attention is completely absorbed by the activity  All the attention is concentrated on the relevant stimuli.  People become so involved in what they are doing that the activity becomes spontaneous, almost automatic; they stop being aware of themselves as separate from the actions they are performing  "Flow." -Describes well the sense of seemingly effortless movement.  does not happen without the application of skilled performance.  -While it lasts consciousness works smoothly, action follows action seamlessly. In normal life, we keep interrupting what we do with doubts and questions.  in flow there is no need to reflect, because the action carries us forward	The reason it is possible to achieve such complete involvement in a flow experience is that goals are usually clear, and feedback immediate  Unless a person learns to set goals and to recognize and gauge feedback in such activities, she will not enjoy them  where goals are not clearly set in advance, a person must develop a strong personal sense of what she intends to do  The kind of feedback we work toward is in and of itself often unimportant. - Feedback: What makes this information valuable is the symbolic message it contains: that I have succeeded in my goal. Such knowledge creates order in consciousness, and strengthens the structure of the self.  feedback can be enjoyable, provided it is logically related to a goal in which one has invested psychic energy	Enjoyable activities require a complete focusing of attention on the task at hand thus leaving no room in the mind for irrelevant information  flow improves the quality of experience: the clearly structured demands of the activity impose order, and exclude the interference of disorder in consciousness  The concentration of the flow experience together with clear goals and immediate feedback-provides order to consciousness, inducing the enjoyable condition of psychic negentropy	the flow experience is typically described as involving a sense of control—or, more precisely, as lacking the sense of worry about losing control that is typical in many situations of normal life.  the possibility, rather than the actuality, of control... in principle, in the world of flow perfection is attainable.  This sense of control is also reported in enjoyable activities that involve serious risks, activities that to an outsider would seem to be much more potentially dangerous than the affairs of normal life.  the positive emotion they enjoy is the perfectly healthy feeling of being able to control potentially dangerous forces.  flow experiences, even the seemingly most risky ones, are so constructed as to allow the practitioner to develop sufficient skills to reduce the margin of error to as close to zero as possible  What people enjoy is not the sense of being in control, but the sense of exercising control in difficult situations. It is not possible to experience a feeling of control unless one is willing to give up the safety of protective routines  This sense of being in a world where entropy is suspended explains in part why flow-producing activities can become so addictive.	One item that disappears from awareness... it is our own Self  The loss of the sense of a self separate from the world around it is sometimes accompanied by a feeling of union with the environment  Preoccupation with the self consumes psychic energy because in everyday life we often feel threatened. Whenever we are threatened we need to bring the image we have of ourselves back into awareness, so we can find out whether or not the threat is serious, and how we should meet it.  In flow there is no room for self-scrutiny. Because enjoyable activities have clear goals, stable rules, and challenges well matched to skills, there is little opportunity for the self to be threatened  This growth of the self occurs only if the interaction is an enjoyable one, that is, if it offers nontrivial opportunities for action and requires a constant perfection of skills  An enjoyable activity offers nontrivial opportunities for action and requires a constant perfection of skills	One of the most common descriptions of optimal experience is that time no longer seems to pass the way it ordinarily does. The objective, external duration we measure with reference to outside events is rendered irrelevant by the rhythms dictated by the activity.  During the flow experience the sense of time bears little relation to the passage of time as measured by the absolute convention of the clock. P66  It is not clear whether this dimension of flow is just an epiphenomenon- a by-product of the intense concentration required for the activity at hand-or whether it is something that contributes in its own right to the positive quality of the experience. losing track of the clock is not one of the major elements of enjoyment p67
	0		0		0	0	

Bold text highlights a relevant link and numbers provide a relatedness ranking, with 0/1 = highly related to 5 = somewhat related



<p><b>3. Final or Autonomous Phase</b></p> <p>The skills you have learnt become increasing automatic. - You think less about what you are doing and external stimulus has less of an effect on your performance</p> <ul style="list-style-type: none"> <li>Skills require less processing – they can be carried on while new learning is in progress or while engaged in other activities</li> <li>Speed and efficiency can continue to increase but at a continually decreasing rate.</li> <li>Continued practise on a predictable activity renders that activity less susceptible to interference from the second task, thus allocating more capacity to the second task and enhancing performance there.</li> </ul>	<p>Optimal experiences are reported to occur within sequences of activities that are goal-directed and bounded by rules</p> <p>Any activity contains a bundle of opportunities for action, or "challenges," that require appropriate skills to realize.</p> <p>For those who don't have the right skills, the activity is not challenging; it is simply meaningless</p>	<p><b>When all a person's relevant skills are needed to cope with the challenges of a situation, that person's attention is completely absorbed by the activity</b></p> <p>All the attention is concentrated on the relevant stimuli.</p> <p><b>*People become so involved in what they are doing that the activity becomes spontaneous, almost automatic; they stop being aware of themselves as separate from the actions they are performing</b></p> <p>"flow."</p> <p>"Describes well the sense of seemingly effortless movement.</p> <p>does not happen without the application of skilled performance.</p> <p>"While it lasts consciousness works smoothly, action follows action seamlessly. In normal life, we keep interrupting what we do with doubts and questions.</p> <p>in flow there is no need to reflect, because the action carries us forward</p>	<p>The reason it is possible to achieve such complete involvement in a flow experience is that goals are usually clear, and feedback immediate</p> <p>Unless a person learns to set goals and to recognize and gauge feedback in such activities, she will not enjoy them</p> <p>where goals are not clearly set in advance, a person must develop a strong personal sense of what she intends to do</p> <p>The kind of feedback we work toward is in and of itself often unimportant. – Feedback: What makes this information valuable is the symbolic message it contains: that I have succeeded in my goal. Such knowledge creates order in consciousness, and strengthens the structure of the self.</p> <p>feedback can be enjoyable, provided it is logically related to a goal in which one has invested psychic energy</p>	<p><b>Enjoyable activities require a complete focusing of attention on the task at hand-thus leaving no room in the mind for irrelevant information</b></p> <p><b>flow improves the quality of experience: the clearly structured demands of the activity impose order, and exclude the interference of disorder in consciousness</b></p> <p>The concentration of the flow experience-together with clear goals and immediate feedback-provides order to consciousness, inducing the enjoyable condition of psychic negentropy</p>	<p><b>the flow experience is typically described as involving a sense of control—or, more precisely, as lacking the sense of worry about losing control that is typical in many situations of normal life</b></p> <p>the possibility, rather than the actuality, of control... in principle, in the world of flow perfection is attainable.</p> <p>This sense of control is also reported for enjoyable activities that involve serious risks, so an outsider would seem to be much more potentially dangerous than the affairs of normal life.</p> <p>the positive emotion they enjoy is the perfectly healthy feeling of being able to control potentially dangerous forces.</p> <p><b>flow experiences, even the seemingly most risky ones, are so constructed as to allow the practitioner to develop sufficient skills to reduce the margin of error to as close to zero as possible</b></p> <p>What people enjoy is not the sense of being in control, but the sense of exercising control in difficult situations. It is not possible to experience a feeling of control unless one is willing to give up the safety of protective routines</p> <p>This sense of being in a world where entropy is suspended explains in part why flow-producing activities can become so addictive.</p>	<p>One item that disappears from awareness... it is our own Self</p> <p><b>The loss of the sense of a self separate from the world around it is sometimes accompanied by a feeling of union with the environment</b></p> <p>Preoccupation with the self consumes psychic energy because in everyday life we often feel threatened. Whenever we are threatened we need to bring the image we have of ourselves back into awareness, so we can find out whether or not the threat is serious, and how we should meet it.</p> <p><b>In flow there is no room for self-scrutiny. Because enjoyable activities- have dear goals, stable rules, and challenges well matched to skills, there is little opportunity for the self to be threatened</b></p> <p><b>This growth of the self occurs only if the interaction is an enjoyable one, that is, if it offers nontrivial opportunities for action and requires a constant perfection of skills</b></p> <p>An enjoyable activity offers nontrivial opportunities for action and requires a constant perfection of skills</p>	<p>One of the most common descriptions of optimal experience is that time no longer seems to pass the way it ordinarily does. The objective, external duration we measure with reference to outside events is rendered irrelevant by the rhythms dictated by the activity.</p> <p>During the flow experience the sense of time bears little relation to the passage of time as measured by the absolute convention of the clock. P66</p> <p>It is not clear whether this dimension of flow is just an epiphenomenon- a by-product of the intense concentration required for the activity at hand-or whether it is something that contributes in its own right to the positive quality of the experience. losing track of the clock is not one of the major elements of enjoyment p67</p>
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1

0

**Bold text highlights a relevant link and numbers provide a relatedness ranking, with 0/1 = highly related to 5 = somewhat related**

## A.2 - EGameFlow Questionnaire

F.-L. Fu et al./Computers &amp; Education 52 (2009) 101–112

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**Table 2**  
Scale of EGameFlow

Factor	Item no.	Content
Concentration	C1	<i>The game grabs my attention<sup>a</sup></i>
	C2	<i>The game provides content that stimulates my attention<sup>a</sup></i>
	C3	Most of the gaming activities are related to the learning task
	C4	No distraction from the task is highlighted
	C5	Generally speaking, I can remain concentrated in the game
	C6	I am not distracted from tasks that the player should concentrate on
	C7	I am not burdened with tasks that seem unrelated
	C8	Workload in the game is adequate
Goal Clarity	G1	Overall game goals were presented in the beginning of the game
	G2	Overall game goals were presented clearly
	G3	Intermediate goals were presented in the beginning of each scene
	G4	Intermediate goals were presented clearly
	G5	<i>I understand the learning goals through the game<sup>a</sup></i>
Feedback	F1	I receive feedback on my progress in the game
	F2	I receive immediate feedback on my actions
	F3	I am notified of new tasks immediately
	F4	I am notified of new events immediately
	F5	I receive information on my success (or failure) of intermediate goals immediately
	F6	<i>I receive information on my status, such as score or level<sup>a</sup></i>
Challenge	H1	<i>I enjoy the game without feeling bored or anxious<sup>a</sup></i>
	H2	<i>The challenge is adequate, neither too difficult nor too easy<sup>a</sup></i>
	H3	The game provides "hints" in text that help me overcome the challenges
	H4	The game provides "online support" that helps me overcome the challenges
	H5	The game provides video or audio auxiliaries that help me overcome the challenges
	H6	<i>My skill gradually improves through the course of overcoming the challenges<sup>a</sup></i>
	H7	<i>I am encouraged by the improvement of my skills<sup>a</sup></i>
	H8	The difficulty of challenges increase as my skills improved.
	H9	The game provides new challenges with an appropriate pacing
	H10	The game provides different levels of challenges that tailor to different players
Autonomy	A1	<i>I feel a sense of control the menu (such as start, stop, save, etc.)<sup>a</sup></i>
	A2	<i>I feel a sense of control over actions of roles or objects<sup>a</sup></i>
	A3	<i>I feel a sense of control over interactions between roles or objects<sup>a</sup></i>
	A4	<i>The game does not allow players to make errors to a degree that they cannot progress in the game<sup>a</sup></i>
	A5	<i>The game supports my recovery from errors<sup>a</sup></i>
	A6	<i>I feel that I can use strategies freely<sup>a</sup></i>
	A7	I feel a sense of control and impact over the game
	A8	I know next step in the game
	A9	I feel a sense of control over the game
Immersion	I1	I forget about time passing while playing the game
	I2	I become unaware of my surroundings while playing the game
	I3	I temporarily forget worries about everyday life while playing the game
	I4	I experience an altered sense of time
	I5	I can become involved in the game
	I6	I feel emotionally involved in the game
	I7	I feel viscerally involved in the game
Social Interaction	S1	I feel cooperative toward other classmates
	S2	I strongly collaborate with other classmates
	S3	The cooperation in the game is helpful to the learning
	S4	The game supports social interaction between players (chat, etc)
	S5	The game supports communities within the game
	S6	The game supports communities outside the game
Knowledge Improvement	K1	The game increases my knowledge
	K2	I catch the basic ideas of the knowledge taught
	K3	I try to apply the knowledge in the game
	K4	The game motivates the player to integrate the knowledge taught
	K5	I want to know more about the knowledge taught

<sup>a</sup> Item underlined was deleted after validity and reliability tested.



## Appendix B – GeoThermal World

### B.1 - Instructors' guidelines

#### GEOTHERMAL FIELD EXPERIMENT – INSTRUCTIONS TO INSTRUCTORS

Instructors: Ben K, Darren G, & Josh B

##### BASICS:

- This instrument is used to assess how student's learn in the field compared to a geothermal videogame we are developing.
- Your job as instructors are to lead the students through a **traditional** field exercise on how to observe, characterize and measure data from a geothermal hotpool.
- They will take notes, as they've been taught (previously) in their notebooks onto a piece of paper, which we will collect for research purposes after the day is completed.
- Please read through the **activity description**, which is shown below:

##### MOST IMPORTANT THINGS TO KNOW:

TRADITIONAL FIELD TEACHING	<ul style="list-style-type: none"> <li>- Teach the material below as you normally would in the field.</li> <li>- Usually professors guide/lead students through an activity in a very <b>linear fashion</b> (e.g. First we do this, then we do this, this is why). This is how I would like you to approach the experiment. Other instructors are much more dynamic with their order in which they explain things, and will allow students to guide the process (which is awesome), but for this time around, lets try a linear, traditional approach.</li> </ul>
ASKING QUESTIONS & TEAM-TEACHING	<ul style="list-style-type: none"> <li>- You CAN use Socratic Method (students asking a question, you respond by asking an additional question, but you do not give them the answer. You guide their decision-making but you do not just tell them).</li> <li>- You CAN invite questions. If you feel that the students do not understand you, you can pose questions in a manner that you usually do.</li> <li>- If one instructor is talking, and you feel like you would like to add something; Feel Free to do so. Demonstrators can help here, and you may call on them like you normally would.</li> </ul>
WHAT + then HOW & WHY	<ul style="list-style-type: none"> <li>- Each <b>task</b> will be presented as:               <ol style="list-style-type: none"> <li>1. What are we doing next? (which tool, here's this tool)</li> <li>2. Go through the <b>steps</b> of how to use the tool. (<b>steps</b>: first you turn it on, then you pick this spot to read it (why), and then you do this...)</li> </ol> </li> </ul>

	<b>while</b> explaining the <b>why</b> . Why do we take readings here, and not here?)
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**WORD DEFINITIONS:**

**Tools-based Activity** = The activity the students will participate in for learning about using Geothermal Tools. When we start the activity, we will use this phrase (to separate it from other fieldwork they will do later this day)

**Task** = A part of the activity, which involved learning how to use a specific tool (e.g. Collectively, all the steps you take when measuring pH with a pH probe)

**Steps** = The specific steps you took when using a new tool (e.g. Turning on the pH meter – one step, then putting the tool into the hot pool – another step)

**GEOHERMAL TOOLS-BASED ACTIVITY.**

For each **TASK**, state

1. The What (what are they doing next),
2. The Goal (The best result possible, ‘Our goal is to effectively measure pH from a sample location)
3. The Why (why are we doing this), &
4. The HOW (all the steps you take to accomplish this)

**BEFORE the activity:**

☐ Pre-Task 1. **INFO & CONSENT** - Before going to the field site, Researcher (Dohaney) will hand out forms and get consent from the students who will be participating. I will give these out to all students, including the Earth Systems.

☐ Pre-Task 2: **PRE-TEST AND PRE-QUESTIONNAIRE** - Dohaney and Bradshaw will give a ‘Pre-questionnaire’ to the students to establish a baseline for measuring flow, and learning gains.

**In the field:**

☐ Task 1 – **INTRODUCTION** - Dohaney and Bradshaw introduce the context (reasoning) for what they will do:

“ My name is Jackie, and this is Hazel. Our phd research has been dedicated to designing a geothermal videogame. This ‘field reasearch’ will guide this design process.

Today, you are going to go through what we are calling, a ‘tools-based’ field activity. This means you will learn how to observe, measure, and record field data at geothermal hotsprings with your eyes, and tools.

Darren/Ben/Josh will be leading you through this activity. You can behave as you normally do in the field. Please take notes on the piece of paper which we have given you. You can keep this paper until the end of the day, to refer to if you like. Let us know if there are any questions you might have.”

#### ☐ Task 2 – **EXPLAIN THE OVERALL GOALS** – Darren/Ben

“The overall GOAL of this activity is to **Observe, Measure, Characterize & Summarize** a geothermal hotspring location.”

“We will be going through all the Tools you can use to collect and measure data from geothermal features”

##### **Why?**

- We characterize surficial geothermal features because they are our clues to the geologic processes occurring in the subsurface
- We collect data to create a concept model which allows us to understand the geothermal system we are working with
- We characterize geothermal features because it allows us to quantify the geothermal resource, and calculate whether the system is economic (or able to be developed)

#### ☐ Task 3 – **LOCATE WHERE YOU ARE ON THE MAP** – Darren/Ben

**What?:** The first thing we usually will do, is locate ourselves on our orakei korako map.

**Why?:** It is important to know where you are in the landscape. Geothermal features and systems can change from one area to the next. Being specific about your location is a best practice to follow when in the field. Also, by recording the coordinates, you can enter your data into the computer and create geologic maps at a later time.

##### **How:**

- Point out the map on the ‘Notebook’ as to where they will record this information
- Ask one (or more) of the students to use a GPS, to yell out the coordinates, the error, and the elevation for the students to record.
- Ask them to mark on the photo provided where they are located, and to note in their ‘Notebook’ what this pool is called.
- Ask the students to check with each other on where they wrote their x. This will encourage students to talk to, and help one another.

#### ☐ Task 4 – **LOCAL GEOGRAPHIC FEATURES**– Darren/Ben

**What?** Observe the local features (rivers, mountains, and escarpments)

**Why?** The context of the field area is very important for understanding the local scale features.

**How:**

- Ask the students what the prominent geographical features in the area.
- Are there rivers, or mountains or scarps?

#### □ Task 5 – **VISUALLY DESCRIBE THE FEATURE** – Darren/Ben

**What?** Next we visually observe & describe the feature we see. Record your notes under the observations section of the notebook.

**Why?** There are many noteable data that can be acquired from simply looking at the geothermal feature. Visual information reflects the **chemistry**, geologic **setting** and **temperature** of the geothermal waters.

**How:**

- Begin by noting down basic information:

a. **number of features** you are describing – ask the students: how many do you see here?

b. the **colour** of the water. Ask the students, what colour(s) do you see? The colour can be indicative of the chemistry of the waters.

c. Describe the **clarity (or level of transparency)** of the water. Is the water clear? Muddy? Cloudy? The clarity of the water is indicative of the amount of solutes, or solids that are dissolved into the fluid.

d. Describe the **activity** of the pool. Is the water escaping from the feature? Or it still, and not overflowing?

- Is the water bubbling? This indicates either that it is boiling, or that gas is being released.

- A discharging feature is called a **spring**.

- A relatively still pool, that is not overflowing is called a **pool**.

- Does the feature blow up? A **geyser** occurs when water flashes (or changes) to steam very rapidly, and escapes through the cracks in a system and explodes upwards.

e. Do you see **sinter**? Sinter is usually white, flaky, or spiny minerals that form along the edge of hot springs. It can grow radially (around the pool) or if the hot pool is overflowing, down a slope, it can form **terraces**. The presence of sinter indicates that the hot waters flow over the edge of the pool, and deposit minerals when cooled down (e.g. silica – meaning at some recent time, the hot pool is a spring).

f. the **odour** or smell of the pools. What do you smell? Sulphur? None? Both of these are good data to note, and is related to the amount of H<sub>2</sub>S anion. Acid sulphate pools often have a slightly sulphur smell.

- Tell them to feel free to make descriptions in your own words. You do not need to know all the names of the features, but it is very important to describe what you see.

#### □ Task 6 – **DRAW FIELD SKETCHES OF THE FEATURE** – Darren/Ben

**What?** While observing the features, it is good practice to draw (or take photos of) the feature that you see. Note close-up details, and general (overall details).

**Why?** Describing how (or documenting; photos) is good for illustrating the important aspects of the pool. This is relevant for the monitoring of pools (to note visual changes over time).

**How?**

- Point out the overall features (shape, discharge, colours).
- Ask them to **sketch** and **label** the features that they draw.
- Remind students to remember to use a scale
- All of the visually described data (ABOVE) like colour, presence and shape of sinter, algae colors and extent are all examples of features that are good to sketch.

#### □ Task 7 – **TAKE THE TEMPERATURE OF THE WATERS** - Josh

**What?** Use the temperature probe to measure several temperature readings. The aim is to get the highest temperature, and to try several spots around the pool.

**Why?** Taking measured data can help quantify, and compare geothermal features and systems. The temperature of geothermal waters at the surface is important for characterizing the geothermal resource in the subsurface.

**How?**

- Place the temperature probe in the hotpool near where the water discharges (if it does). We do this because it represents the ‘freshest’ source of water from the subsurface.
- Be sure to allow the machine the time to equilibrate
- Read off the temperature to the students
- Give them context – temperatures of \_\_\_ and \_\_\_ are considered very economic, while temps of \_\_\_ and \_\_\_ are not.
- Measure and record x number of readings are necessary for statistical purposes.
- calculate an average?

□ Task 8 - **TAKE THE pH OF THE WATERS** - Josh

**What?** Use the pH and conductivity meter to measure the pH of the hotpool.

**Why?** pH is a key measure that allows us to discriminate between different types of hotpools (based on chemistry).

**How?**

- Place the pH/conductivity meter in the hotpool near where the water discharges (if it does). We do this because it represents the ‘freshest’ source of water from the subsurface.
- Be sure to allow the machine the time to equilibrate.
- Read off the pH to the students. Ask them to record it.
- Take x number of readings are necessary for statistical purposes.
- Does not require an average, as pH will generally not vary much from place to place.

□ Task 9 – **TAKE THE CONDUCTIVITY OF THE WATERS** - Josh

**What?** Use the pH/conductivity meter to measure the conductivity of the hotpool.

**Why?** Conductivity is linked to the level of solutes that are dissolved into the water. The most common molecule is Chloride. (economic) Geothermal resources often have high chloride, and therefore high conductivities.

**How?**

- Place the pH/conductivity meter in the hotpool near where the water discharges (if it does). We do this because it represents the ‘freshest’ source of water from the subsurface.
- Be sure to allow the machine the time to equilibrate.
- Read off the conductivity to the students (include units). Ask them to record it.
- Take x number of readings are necessary for statistical purposes.
- Calculate the average values recorded.

□ Task 10 – **TAKE A SAMPLE, FOR CHEMISTRY** - Josh

**What?** Use a water vial, and heat resistant gloves, to carefully and safely get a sample of water from the hotpool.

**Why?** We take water samples to send away to an analytical lab, in order to get more detailed chemistry of the water. Water geochemistry is important for understanding the geologic and hydrogeologic processes occurring. The geochemistry also allows us to classify the water sample.

**How?**

- Put on heat resistant gloves
- Get close to the hot pool edge, and illustrate an area where you can safely dip the water vial into the pool to get some water.

- In order to get statistical and (possible) chemical variation be sure to take x number of samples per pool.
- Seal the water sample vial with tape, so that condensation does not occur (allowing some fluid to escape)

☐ Task 11 – **COMPLETE THE SUMMARY LOG** – Darren/Ben

**What?** On the back of the ‘Notebook’, ask students to fill out the summary log.

**Why?** Summarizing the location will allow you to quickly recap what you have observed, and in the future, will allow you to compare one location to another.

**How?**

- Read through the columns
- Ask students if there are any that they do not understand.

**THE END**

**AFTER the activity:**

☐ Post-Task 1. – **COLLECT NOTEBOOKS** – Dohaney

What? Dohaney will collect the notebooks for her research

☐ Post-Task 2. – **GIVE POST-TEST and POST QUESTIONNAIRE** - Dohaney

What? Dohaney will ask students to complete a post-questionnaire

## B.2 – Skills Test

### I. Tools-based Activity Pre-post Concept Test

**Instructions:** Please answer the questions to the best of your ability, and ask the researcher if you need help. Some of these questions are the same as before. Please do not discuss the contents of this test with the other participants. Remember that this is entirely confidential and none of your instructors or peers will access this information.

**Question 1.** List as many types of **visual observation** data as you can, that can be collected at a geothermal hot spring.

For each type of data, write the **reasoning** for why you collect it (what is the purpose for collecting it?)

Data	Reasoning



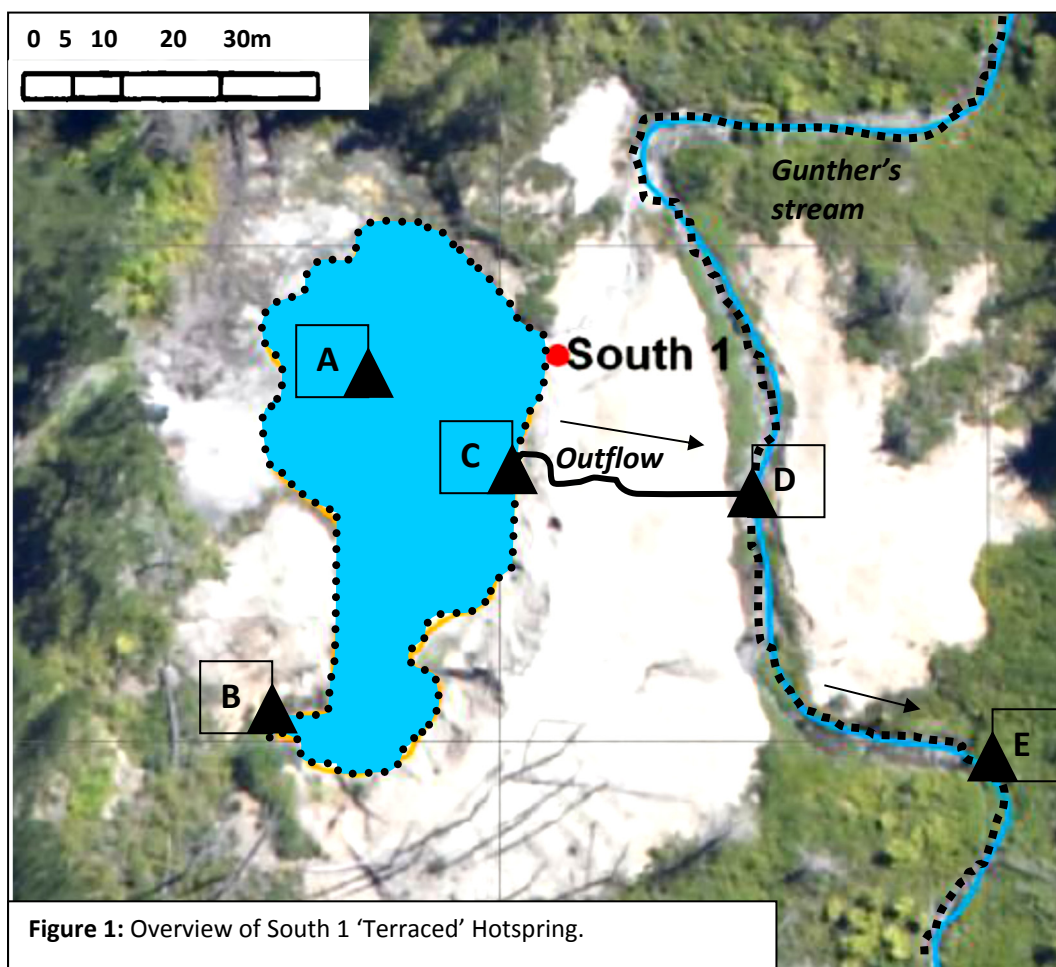


Figure 1: Overview of South 1 'Terraced' Hotspring.

**Question 2:** Using Figure 1 to help you, answer the following question. You are doing fieldwork on foot.

- a. If you could take only one Conductivity reading, which location would be the best (*most likely to give you the most representative data*)? A B C D or E
- b. If you could take only one Temperature reading, which location would be the best (*most likely to give you the most representative data*)? A B C D or E
- c. The white coloured material in the photo is most likely...?  
A. Rhyolite; B. Granite; C. Ash deposit; D. Sinter; E. Algal Mat

**Question 3:** Of the following, which is **NOT** an effective method when sampling &/or visiting geothermal hot springs? (**Select all that apply**)

a. Wearing heat resistant gloves	b. Wearing closed-toed shoes	c. Smelling the hot spring
d. Tasting a very small amount of the water	e. Using a rock hammer to break off rock nearby	f. Digging into the ground near the springs
g. Taking at least 2 Conductivity measurements from each spring.	h. Taking at least 10 or more pH readings from the same spring	i. Taking several water samples for geochemical analysis from the same spring

### B.3 – Question 1 Marking Scheme

Question 1. (a) List as many types of visual observation data as you can, that can be collected at a geothermal hot spring. (b) For each type of data, write the reasoning for why you collect it (what is the purpose for collecting it?) (/48 r					
code	Data type (1 each)	Reasoning (Excellent) (2.5 or 3)	Reasoning (Average) (1.5 to 2 marks)	Reasoning (Poor) (0-1 marks)	response
w1	Color of the water	Different <b>chemical compositions</b> of hot springs will contain different <b>minerals, solutes, and bacterial</b> species which are <b>temperature dependent</b> , usually arranged in layers around the hot spring. <b>Example:</b> Some springs are richly blue, in the centers which is due to the absence of particles/purity (due to extreme temperatures) leaving it a brilliant blue color. (2.5 to 3 Marks)	Different <b>chemical compositions</b> of hot springs will contain different <b>minerals, solutes, and bacterial</b> species which are <b>temperature dependent</b> , usually arranged in layers around the hot spring. (1.5 to 2 Marks)	Different <b>chemical compositions</b> of hot springs will contain different species, no example (1 mark). No reason provided (0 marks).	Water Property
	Clarity of the water	The <b>presence and proportion</b> of minerals, particulates (total dissolved solids), and bacterial species will create clear, cloudy or opaque (muddy) waters. This is due to the acidity and temperature of the gases and fluids rising into the feature. Mudpools are fueled by acid waters, with large amounts of H <sub>2</sub> S dissolving rocks into clay.	The <b>presence OR proportion</b> of minerals, particulates (total dissolved solids), and bacterial species will create clear, cloudy or opaque (muddy) waters. e.g Mudpools are fueled by acid waters, with large amounts of H <sub>2</sub> S dissolving rocks into clay.	The <b>presence OR proportion</b> of minerals, particulates (total dissolved solids), and bacterial species will create clear, cloudy or opaque (muddy) waters. No example	Water Property
	Smell	Different <b>chemistries</b> of hot springs will emit different smells based on the dominant <b>gas phase(s)</b> being released. (ex) The most noticeable gas is hydrogen sulphide which smells of rotten eggs. The <b>strength</b> and distinct smell of the gas will indicate the level of emissions coming from the spring. Mudpools and fumaroles have strong sulphur emissions, while hot springs have less potent smells. <b>Algae</b> may emit earthy-decaying smells based on the species. (2.5 to 3 Marks)	Different <b>chemistries</b> of hot springs will emit different smells. <b>Example:</b> Hydrogen sulphide is the most common gas released in geothermal areas which smells of rotten eggs. The <b>strength</b> of the smell is also notable. (1.5 to 2 Marks)	Different <b>chemistries</b> of hot springs will emit different smells (no example). (1 mark) No reason provided (0 marks)	Water Property
	Activity of the pools, Presence of steam/boiling/bubbles	The <b>temperature and discharge</b> rate of a hot spring is very important for understanding how active a hot spring is. If a hot spring is above 100 deg C, steam and 'boiling' will be observed. <b>Gases</b> can also be released as bubbles from a hot spring (e.g. CO <sub>2</sub> , H <sub>2</sub> S, and H <sub>2</sub> O). <b>The activity of the spring</b> is relevant for understanding the hydrogeology (discharging (more notable by water flowing up over the rim of the spring, and away); still; slightly bubbling) and also for noting <b>changes in activity</b> over time.	The <b>temperature OR discharge</b> rate OR level of activity of a hot spring is very important for understanding how active a hot spring is and also for noting <b>changes in activity</b> over time. E.g. pools that overflow are springs, or mudpots release gas bubbles	The <b>temperature OR discharge</b> rate OR level of activity of a hot spring is very important for understanding how active a hot spring is and also for noting <b>changes in activity</b> over time. (no example)	Water Property
c1	Presence of/colour of mineralogy adjacent or within the pools	Different <b>chemical compositions</b> of hot springs will contain different minerals, solutes, and bacterial species. The color of the minerals are indicative of the <b>metal ions</b> (and bacterial composition) E.g. Purple (from cinnabar – mercury sulfide), Orange (from realgar – arsenic sulfide), and Yellow to Grey (from sulfur).	Different <b>chemical compositions</b> of hot springs will contain different minerals. E.g. Purple (from cinnabar – mercury sulfide), Orange (from realgar – arsenic sulfide), and Yellow to Grey (from sulfur).	Different <b>chemical compositions</b> of hot springs will contain different minerals, solutes, and bacterial species.	Close-up
c2	Presence /textures of sinter	The textures, shapes/landforms, thicknesses and colours of the silica sinter will indicate the history and evolution of the geothermal area. This is useful for monitoring changes and understanding past activity. The silica sinter forms different textures based on physical, chemical and microbial conditions.	The textures, AND/OR shapes/landforms, AND/OR thicknesses AND/OR colours of the silica sinter will indicate the history and evolution of the geothermal area. This is useful for monitoring changes, and understanding past activity. The silica sinter forms different textures based on physical, chemical and microbial conditions.	The textures, OR shapes/landforms, OR thicknesses OR colours of the silica sinter will indicate the history and evolution of the geothermal area. This is useful for monitoring changes, and understanding past activity. The silica sinter forms different textures based on physical, chemical and microbial conditions.	Close-up
c3	Presence/absence of algae and life	The <b>type</b> (colour), <b>density</b> , and <b>textures</b> of algae (extremophiles, thermophiles) around geothermal areas are dependent of <b>temperature</b> , and <b>pH</b> of the soil, and <b>activity</b> and <b>pH</b> of the waters. E.g. Red/orange algae are typically found in warmer areas (can tolerate conditions), while dark green is associated with cooler temperatures, rich with chlorophyll.	The <b>type</b> (colour), AND/OR <b>density</b> , AND/OR <b>textures</b> of algae (extremophiles, thermophiles) around geothermal areas are dependent of <b>temperature</b> , AND/OR <b>pH</b> of the soil, AND/OR <b>activity</b> AND/OR <b>pH</b> of the waters. E.g. Red/orange algae are typically found in warmer areas (can tolerate conditions), while dark green is associated with cooler temperatures, rich with chlorophyll.	The <b>type</b> (colour), OR <b>textures</b> of algae (extremophiles, thermophiles) around geothermal areas are dependent of <b>temperature</b> , OR <b>pH</b> of the soil, OR <b>activity</b> OR <b>pH</b> of the waters.	Close-up
c4	Presence/absence of vegetation	The <b>type</b> , and <b>density</b> of vegetation around geothermal areas is dependent on the <b>temperature</b> and <b>pH</b> of the ground. E.g. <b>Mosses and lichen</b> can survive relatively close to the hotpools; while <b>shrubs</b> such as Manuka can survive further back.	The <b>type</b> , OR <b>density</b> of vegetation around geothermal areas is dependent on the <b>temperature</b> AND/OR <b>pH</b> of the ground. E.g. <b>Mosses and lichen</b> can survive relatively close to the hotpools; while <b>shrubs</b> such as Manuka can survive further back	The <b>type</b> , OR <b>density</b> of vegetation around geothermal areas is dependent on the <b>temperature</b> and <b>pH</b> of the ground.	Close-up
o1	Number of pools (features)	The number of features you are describing is a straightforward observation that is required for clarity of the note taking, and the reader. It also allows you to determine (later) the spatial distribution, and density of geothermal activity in the area.	The number of features you are describing is a straightforward observation that is required for clarity of the note taking, and the reader OR It also allows you to determine (later) the spatial distribution OR and density of geothermal activity in the area.	The number of features allows you to map the geothermal area.	other
	Feature size (extent); Dimensions	Basic <b>size, depth, and extent</b> information is required to understand the geologic, hydrogeologic and structural controls of the system. Also, these are useful for calculating and modelling fluid flow (discharge), and for monitoring activity over time and for producing geothermal system maps (extent).	Basic <b>size OR depth</b> , AND/OR <b>extent</b> information is required to understand the geologic, hydrogeologic and structural controls of the system.	Basic <b>size OR depth</b> , OR <b>extent</b> information is required to understand the geologic, hydrogeologic and structural controls of the system.	other
	Proximity to other geologic features/wider geologic features	There are many geologic features that are worth noting at a geothermal area. <b>Hydrogeologic</b> features such as streams and lakes are important for understanding the sources of water in the area; The <b>source</b> of the hot water is usually related to some form <b>volcanic activity</b> ; <b>Locations</b> and <b>description</b> of fault surfaces can help understand the traps or conduits for fluid flow.	<b>Hydrogeologic</b> features such as streams and lakes are important for understanding the sources of water in the area; AND/OR The <b>source</b> of the hot water is usually related to some form <b>volcanic activity</b> ; AND/OR <b>Locations</b> and <b>description</b> of fault surfaces can help understand the traps or conduits for fluid flow.	<b>Hydrogeologic</b> features such as streams and lakes are important for understanding the sources of water in the area; OR The <b>source</b> of the hot water is usually related to some form <b>volcanic activity</b> ; OR <b>Locations</b> and <b>description</b> of fault surfaces can help understand the traps or conduits for fluid flow.	other
cl1	Feature type	Using some of the visual obsvs noted here, you can <b>categorize</b> geothermal features into basic features: a. hot springs (discharge), hot pools (no discharge), mudpools, and barren ground/fumaroles. This categorization is very important for characterizing and <b>mapping (spatially)</b> a geothermal system. It is also important for knowing where you are in the system (relationship to the water table)	Using some of the visual obsvs noted here, you can <b>categorize</b> geothermal features into basic features: a. hot springs (discharge), hot pools (no discharge), mudpools, and barren ground/fumaroles. This categorization is very important for characterizing and <b>mapping (spatially)</b> a geothermal system.	Using some of the visual obsvs noted here, you can <b>categorize</b> geothermal features into basic features: a. hot springs (discharge), hot pools (no discharge), mudpools, and barren ground/fumaroles.	classification

## ***B.4 – Adapted EGameFlow v1***

### **1. Concentration**

Most of the tasks during the tools-based activity were related to each other.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

I was not burdened with tasks that seemed unrelated.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
-------------------	----------	---------	-------	----------------

Workload in the activity was adequate.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
-------------------	----------	---------	-------	----------------

### **2. Goal Clarity**

The overall goals for the tools-based activity were presented at the beginning of the day.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
-------------------	----------	---------	-------	----------------

The overall goals of the activity were presented clearly.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
-------------------	----------	---------	-------	----------------

Before a new task, the goal of the task was explained clearly.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
-------------------	----------	---------	-------	----------------

### **3. Feedback**

During the activity, I received feedback on my progress.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
-------------------	----------	---------	-------	----------------

During the activity, I received immediate feedback on my actions.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
-------------------	----------	---------	-------	----------------

During the activity, I received immediate information on my success (or failure) of the tool usage goals.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
-------------------	----------	---------	-------	----------------

#### 4. Challenge

During the activity the difficulty of the challenges increased as my skills improved.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
-------------------	----------	---------	-------	----------------

The tools-based activity provided new challenges with appropriate pacing.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
-------------------	----------	---------	-------	----------------

The tools-based activity provided different levels of challenge that tailored to my ability

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
-------------------	----------	---------	-------	----------------

#### 5. Autonomy

I felt a personal sense of control and impact during the activity.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
-------------------	----------	---------	-------	----------------

I could anticipate what the next steps would be during the tool-based tasks.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
-------------------	----------	---------	-------	----------------

I felt a sense of control over the tasks that I was asked to do.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
-------------------	----------	---------	-------	----------------

#### 6. Immersion

I forget about time passing while involved in the tools-based tasks.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
-------------------	----------	---------	-------	----------------

I temporarily forget any worries about everyday life while involved in the tools-based tasks.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
-------------------	----------	---------	-------	----------------

I felt emotionally involved in the tool-based tasks.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
-------------------	----------	---------	-------	----------------

**7. Social Interaction**

I felt cooperative toward the other students

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
-------------------	----------	---------	-------	----------------

I strongly collaborated with the other students

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
-------------------	----------	---------	-------	----------------

The cooperation I experienced overall during the tools-based activity was helpful to my learning

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
-------------------	----------	---------	-------	----------------

**8. Enjoyment**

I felt a sense of enjoyment whilst undertaking the tools-based activity.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
-------------------	----------	---------	-------	----------------

Overall I enjoyed the tools-based activity.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
-------------------	----------	---------	-------	----------------

Overall I would say the tools-based activity work was a fun experience

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
-------------------	----------	---------	-------	----------------

## **B.5 –Ethics Approval**



### **HUMAN ETHICS COMMITTEE**

Secretary, Lynda Griffioen  
Email: [human-ethics@canterbury.ac.nz](mailto:human-ethics@canterbury.ac.nz)

Ref: HEC 2012/21

23 May 2012

Hazel Bradshaw & Jacqueline Dohaney  
HITLab, Geological Sciences  
UNIVERSITY OF CANTERBURY

Dear Hazel and Jacqueline

The Human Ethics Committee advises that your research proposal “Assessing flow, motivation and learning gains of geothermal concepts from a field-based approach compared to a virtual video game (GeoThermal World)” has been considered and approved.

Please note that this approval is subject to the incorporation of the amendments you have provided in your emails of 22 March and 17 May 2012.

Best wishes for your project.

Yours sincerely

A handwritten signature in black ink, appearing to read 'Michael Grimshaw'.

Michael Grimshaw  
**Chair**  
*University of Canterbury Human Ethics Committee*

## Appendix C – Ora – Save the Forest!

### C.1 – Marking Scheme

#### Mark Scheme

##### Answers

0	None given, totally irrelevant
1	Relevant answer (may or may not indicate clearly what is to be measured (e.g. “trunk” and “trunk size/colour” both valid)

##### Reasons

0	None given, totally irrelevant
1	Answer given but no/little/poor explanation of what/why it is relevant (e.g. "how the tree is affected")
2	Answer given with some explanation of relevance (e.g. "whether the tree is affected so much that it dies") or
3	Answer given with good explanation of relevance (e.g. "compare relative growth rates in areas with different pest popn size")
4	Complex and relevant multipart answer showing good insight

Additional score for how many of the things mentioned specifically in the game/sim are included:

- 1 size – specifically DBH (diameter at breast height, just diameter accepted, but not other measurements such as circumference, height, or just size)
- 2 status – is the tree alive? (various wordings allowed as long as intent is clear)
- 3 FCI/folige cover index; cover accepted, also foliage density but not leaf quality/number/count.
- 4 Browse – how many leaves have been nibbled by possums (various wordings allowed as long as intent is clear)
- 5 Tree species

Notes for tree radius/map questions – several people seemed to think that they were trying to get all the information about the forest from a single plot, and as a result wanted to use larger plots within which they would look at sub-plots, or generally were confused because (of course) it would be difficult to draw conclusions from a single plot. It will be interesting to see how that changes with post test results, but is partly a problem with the way we phrased the question, and partly (potentially) needs explaining more in the game/sim that the first levels are tutorial-esque and not supposed to be the whole big picture straight away.

How large a radius?

1: 2 m, 2: 7m, 3: 15 m, 4: 30 m

Mark scheme for answer

1 point for if it ties in the with size answer given

1 point for if it is a sensible scientific argument

1 bonus point for getting the idea of large for sample size but not too large for time taken to monitor

1 bonus point for “it says so in the game” or “recommended by the presenter”

Which plot on the map?

Area 1 is the “correct” one.

Mark scheme

1 point for mentioning tree sizes

1 point for mentioning tree density (e.g. enough trees to sample within the space/easy to get round the trees in a small time)

1 point for saying it represents the whole area well

1 bonus point for mentioning learning something from game/sim



## C.2 – Skills Test

**Q28 The following questions are the pre-knowledge test.**

Please answer the questions to the best of your ability. The researcher will be there to help if needed. Please do not discuss the contents of this test with the other participants.

Remember the test is entirely confidential and your peers cannot access your information.

**Q29** Tree monitoring is used to record information about individual trees, in order to assess whether damage from pests such as possums is having an impact on their health, growth and reproductive ability. List as many types of observational data (information) as you can that could be collected from a tree monitoring operation (hint: consider what you could measure or estimate by looking at the tree trunk, branches, leaves and flowers/fruit). For each type of data, write the reasoning or purpose for collecting it.

	1	2
	Observational data (e.g. Checking if the tree is alive on repeated observation). (1)	Reason for collecting (e.g. Want to see how the tree fairs long term). (1)
1 (1)		
2 (2)		
3 (21)		
4 (22)		
5 (23)		
6 (24)		
7 (25)		
8 (26)		

**Q30** Please add any comments you had about this section

**Q31** How many trees in a forest would you want to monitor?

- ☐ All of them (1)
- ☐ A few of each species (2)
- ☐ One of each species (3)

**Q32** How could you measure tree canopy health? (tick all you think apply)

- ☐ Count all the leaves on the tree (1)
- ☐ Look up through the leaves from below and see how much sky is visible (2)
- ☐ Decide whether the leaves look mostly healthy or not (3)
- ☐ Compare the way the canopy looks to a set of reference pictures (4)

**Q33** How many leaves can possums nibble on before a tree starts to feel the impact of browse?

- ☐ Less than ¼ of them (1)
- ☐ Up to half of them (2)
- ☐ More than half of them (3)
- ☐ More than ¾ of them (4)

Q34 How large a radius might you look within to choose trees for monitoring?

- ☐ 2 m (1)
- ☐ 7 m (2)
- ☐ 15 m (3)
- ☐ 30 m (4)

Q35 For the question above please explain why?

Q36 Which tree species is the least tasty to possums?

- ☐ Kamahi (1)
- ☐ Hall's totara (2)
- ☐ Southern rata (3)

Q37 Please add any comments you had about this section

Q38 Which of the following plots are well placed to allow you to efficiently record tree monitoring data in the forest? Think about the number and size of trees you might want to observe, and how long it will take you to move between trees. Note: if you do not click in an area you cannot be awarded marks



Q39 Please give reasons for your choice in the question above

Q107 Please add any comments you had about this section

### ***C.3 – Amended EGameFlow Questions v2***

#### **Flow**

Q60 The purpose of this survey is to record your perception of the activity you have just undertaken. There are no right or wrong answers your personal opinion is what matters the most. Please select the response which you feel most closely represents your view on each statement.

#### Q61 Challenge

During the activity the difficulty of the challenges increased as my skills improved (1)

The activity provided new challenges with appropriate pacing (2)

The activity provided different levels of challenge that tailored to my ability (3)

#### Q62 Goal Clarity

The overall goals for the activity were presented at the beginning of the day (1)

The overall goals of the activity were presented clearly (2)

Before a new task, the goal of the task was explained clearly (3)

#### Q63 Feedback

During the activity, I received feedback on my progress (4)

During the activity, I received immediate feedback on my actions (5)

During the activity, I received immediate information on my success (or failure) of the goals (6)

#### Q64 Concentration

Most of the tasks during the activity were related to each other. (1)

I was not burdened with tasks that seemed unrelated. (2)

Workload in the activity was adequate. (3)

#### Q65 Autonomy

I felt a personal sense of control and impact during the activity. (1)

I could anticipate what the next steps would be during the tasks. (2)

I felt a sense of control over the tasks that I was asked to do. (3)

Q66 Immersion involvement

- | I can become involved in the activity. (1)          |
|---|
| I felt emotionally connected with the activity. (2) |
| I felt intuitively involved in the activity. (3)    |

Q67 Immersion time

- | I forget about time passing while involved in the tasks. (1)                          |
|---|
| I temporarily forget any worries about everyday life while involved in the tasks. (2) |
| I become unaware of my surroundings while involved in the activity. (3)               |

Q68 Knowledge

- | The activity increases my knowledge. (1)            |
|---|
| I try to apply the knowledge in the activity. (2)   |
| I want to know more about the knowledge taught. (3) |

Q69 Enjoyment

- | I felt a sense of enjoyment whilst undertaking the activity. (1) |
|--|
| Overall I enjoyed the activity. (2)                              |
| Overall I would say the activity was a fun experience. (3)       |

### ***C.4 - Perceptions on Possum Control - Post***

Q19 The following questions are about your perception of possum control and its practice.

Q20 Are you living or have you lived on a farm or rural property?

- ☐ Yes (1)
- ☐ No (2)
- ☐ Decline to answer (3)

Q21 Do you spend time in outdoor activities in the bush (hiking/hunting/fishing/etc)?

- ☐ Yes (1)
- ☐ No (2)
- ☐ Decline to answer (3)

Q22 The following questions relate to your past experience with possum control.

Have you participated in a regional council consultation about possums? (1)

Have you attended a TBfree information evening? (2)

Have you written letters to the editor on the topic? (3)

Have you researched the topic? (4)

Have you laid bait or traps for possums? (5)

My friends know more about possums than me? (6)

People who know me well say I am a reliable source of information about possum control. (7)

Q23 Please add any comments you had about this section

Q24 Situation in New Zealand.

In NZ possums are a problem. (1)

Possums are only an issue for farmers. (2)

Most people in NZ want the government to control possums better. (3)

The Department of Conservation has enough resources to completely remove possums. (4)

The people I trust think there are more important issues than controlling possums. (5)

The possum problem in NZ is not complex and possum management is easy. (6)

Possums are only a problem because they eat NZ's native plants. (7)

Q25 Local Situation.

Environment Canterbury does as much as it can to control possums. (1)  
Most people I know think possums are a problem on Banks Peninsula. (2)  
We will never be able to completely get rid of possums from Banks Peninsula. (3)

Q26 Perceptions of Practices.

Most people in NZ think trapping is the best way to kill possums. (1)  
My friends are concerned that possums take a long time to die when trapped. (2)  
I would be disturbed to hear that baits can kill insects. (3)  
Not enough research has been done to know if bait can pollute the water. (4)  
No poisons should be used to control possums. (5)

Q27 Please add any comment you had about this section

### ***C.5 - Perceptions on Possum Control – Follow-up***

Q2 Perception of Possum Management      Please give your level of agreement with the following statements

In NZ possums are a problem. (1)

Possums are only an issue for farmers. (2)

The Department of Conservation has enough resources to completely remove possums. (3)

The possum problem in NZ is complex and possum management is difficult. (4)

Possums are only a problem because they eat NZ's native plants. (5)

Q3 Since participating in the experiment:

I have researched the topic. (9)

I am more aware of the impact possums can have on native forests. (1)

I care more about forest health. (2)

I feel more informed about possum impacts on native forests. (3)

I would like to know more about how to control possums in new Zealand. (4)

I think I would notice possum browse on trees more than I did before. (5)

I would look for possum browse while out in the countryside. (6)

I feel I am more aware of the impacts of pest species in New Zealand forests. (7)

I think my interest in possum impacts on NZ forests has increased after participating. (8)

## C.6 – Ethics Approval



### HUMAN ETHICS COMMITTEE

Secretary, Lynda Griffioen  
Email: [human-ethics@canterbury.ac.nz](mailto:human-ethics@canterbury.ac.nz)

Ref: HEC 2013/47/LR-PS

4 December 2013

Hazel Bradshaw  
HIT Lab NZ  
UNIVERSITY OF CANTERBURY

Dear Hazel

Thank you for forwarding to the Human Ethics Committee a copy of the low risk application you have recently made for your research proposal “Pest management game/simulation study”.

I am pleased to advise that this application has been reviewed and I confirm support of the Department’s approval for this project.

Please note that this approval is subject to the incorporation of the amendments you have provided in your email of 26 November 2013.

With best wishes for your project.

Yours sincerely

A handwritten signature in black ink, appearing to read 'L MacDonald'.

Lindsey MacDonald  
**Chair, Human Ethics Committee**



